COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

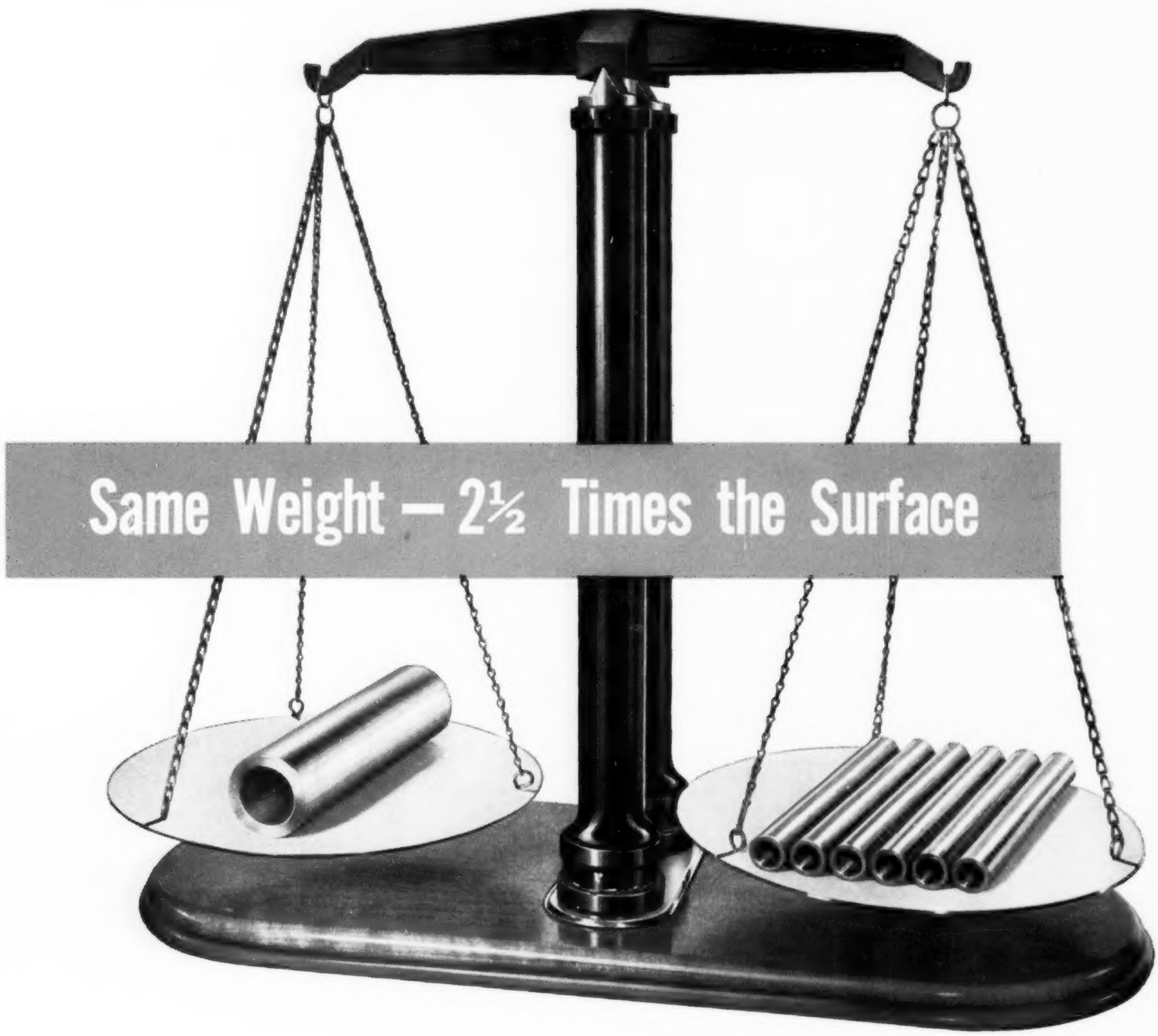
July 1953

Lake Creek Steam Electric Station of Texas Power & Light Company

Design Features of Portsmouth Power Station

ASME Semi-Annual Meeting Highlights

Selection of Power Plant Stacks



The balance scale dramatizes one of the most important advantages of controlled circulation.

On the left side is shown a 1-foot long section of conventional tubing as used in the furnace walls of a natural circulation boiler. On the right side is shown six 1-foot long sections of tubing as used in the furnace walls of a C-E Controlled Circulation Boiler. The weight is the same but the surface area of the small tubes is 2½ times greater. Because controlled circulation permits the use of small-diameter, thin-wall tubes and provides adequate and properly proportioned flow to each circuit it affords the major advantages listed at the right.

Wide recognition of these advantages by leading utilities in all parts of the country has been evidenced by orders over the past 30 months which represent an aggregate capacity of more than 5,000,000 kw.

Fifty per cent reduction in weight of steam generating surfaces for equivalent capacity.

•

Less supporting steel, less building steel and less expensive foundations.

•

Adaptability to higher steam pressures permitting better power station economy.

•

Quicker starting up and shutting down.

•

Greater safety.

ALL TYPES OF STEAM GENERATING, FUEL BURNING AND RELATED EQUIPMENT

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DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

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Feature Articles

Editorials

Departments

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COMBUSTION

Editorials

Trends in Engineering Education

Engineering educators are buffeted by many forces, the resolution of which is sometimes complicated by an overabundance of panaceas. On the one hand is the need for more specialization because of the complexity of technological developments, while on the other is the need for breadth in education—the engineering generalist—in order to comprehend the interaction and the interrelationships of the specialties. There is the cry for more emphasis upon fundamentals, for a broader understanding of the humanities, for graduates with a competency to do everything from basic research in engineering science to supervising construction and taking part in such diverse activities as industrial public relations, electronic design, and heavy-equipment selling.

The recent meeting of the American Society for Engineering Education at the University of Florida provided some evidence of current trends in training for professional service. Many engineering schools are finding it impossible to continue the highly specialized curricula of the 1910–1940 period, for both educators and industrial leaders have learned that industry can provide some of the specialized training. Work in the humanities, particularly skills in communication and in the social sciences, has now assumed a larger role in undergraduate education. In terms of teaching methods, there has been a commendable emphasis upon the importance of creativity and of the integrating effect brought about by courses in engineering analysis and the use of the project approach. Many successful attempts have been made to increase the significant content and the rigor of courses in basic engineering science. Beginnings are being made to develop professional consciousness at the college level and to encourage continuing professional development.

Not all engineering schools are in accord with these trends, and there exists a healthy spirit of skepticism toward some of them. A most interesting investigation is now being conducted by the Committee on Evaluation of Engineering Education of the ASEE to see if it is possible to serve both those engineers engaging in such activities as production, construction, operation and sales and those specialized engineering scientists who are capable of interpreting and using the information being provided by research in engineering sciences. The present feeling is that divergent curricula may be necessary. It will be interesting to see what effect this comprehensive study will have upon engineering education in the years that are to come.

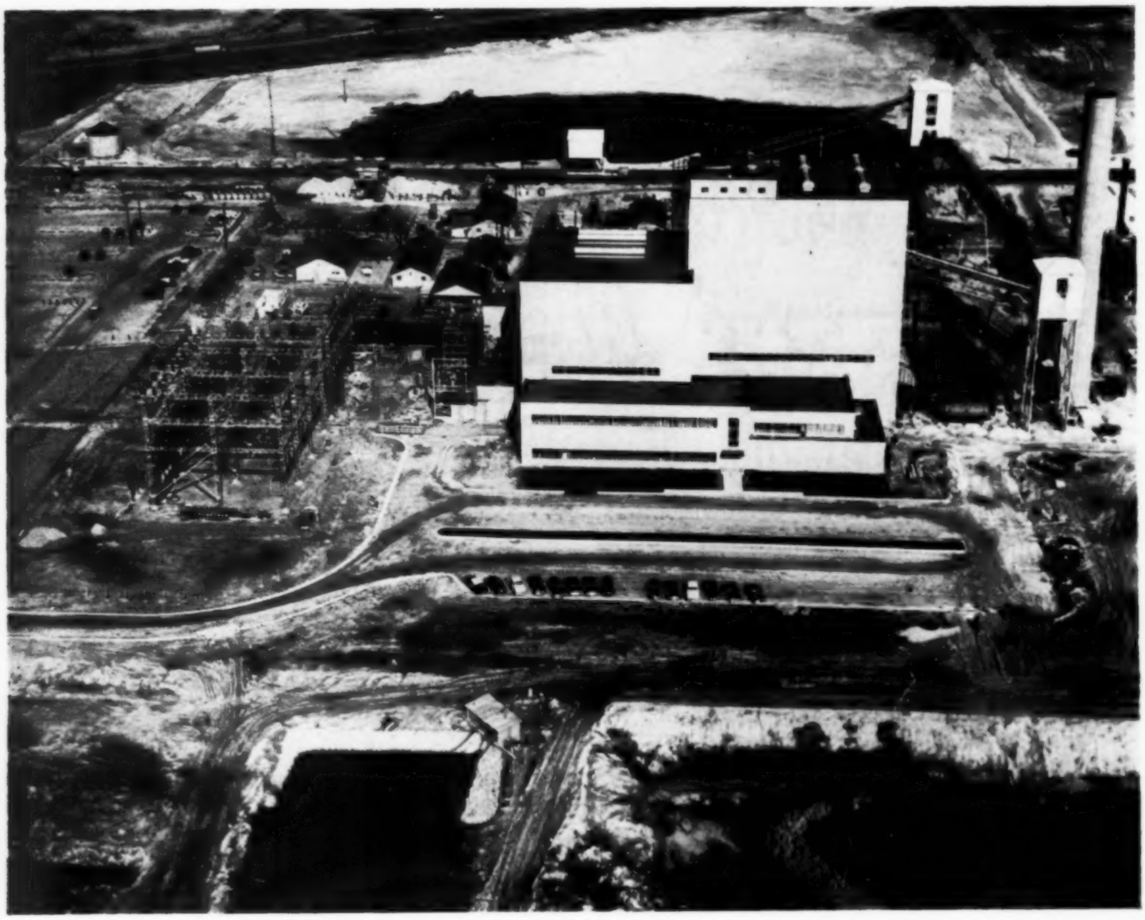
Unit Sizes and Pressures Continue Their Upward Swing

The continued trend toward greater use of very large steam generating units and turbines is shown by a review of the capacities now on order and scheduled for service during the next three years. Axiomatically, although the number of new units shows a decrease over this period, the individual nameplate ratings are increasing. The average size of those to be placed in operation during the current year is approximately 85,000 kw. Progressively, this average will increase to 92,500 kw for 1954 and around 125,000 kw for 1955 and 1956. Of course, scattered installations of much larger units than these averages have been operating for many years, but they have not been of the single-boiler, single-turbine arrangement. There are now building or on order around twenty such units of 200,000 kw nameplate rating and several of 250,000 kw. The largest announced to date will be two of 260,000 kw. Still larger units are in the project stage.

It formerly was considered that few systems were sufficiently extensive to justify units of such size, but widespread interconnection, proved availability, reduced initial unit cost and savings in operating labor have apparently afforded the answer.

Along with the employment of larger units, progress points to still higher steam conditions, as indicated by two separate announcements within the last month of plans and projects to explore the critical pressure range with pressures of the order of 4500 to 5000 pounds per square inch and steam temperatures of 1150 F.

When one considers the parallel work that is in progress by several groups to develop economical nuclear power, it becomes apparent that power engineering is a field that offers wide opportunities for the young engineer.



Design Features of Portsmouth Power Station

This article describes a recently completed 100,000-kw steam-electric station designed and constructed by the Stone & Webster Engineering Corporation in the Hampton Roads area of eastern Virginia. A controlled-circulation steam generator serves a Preferred Standard turbine-generator having throttle conditions of 1450 psig, 1000 F with reheat to 1000 F.

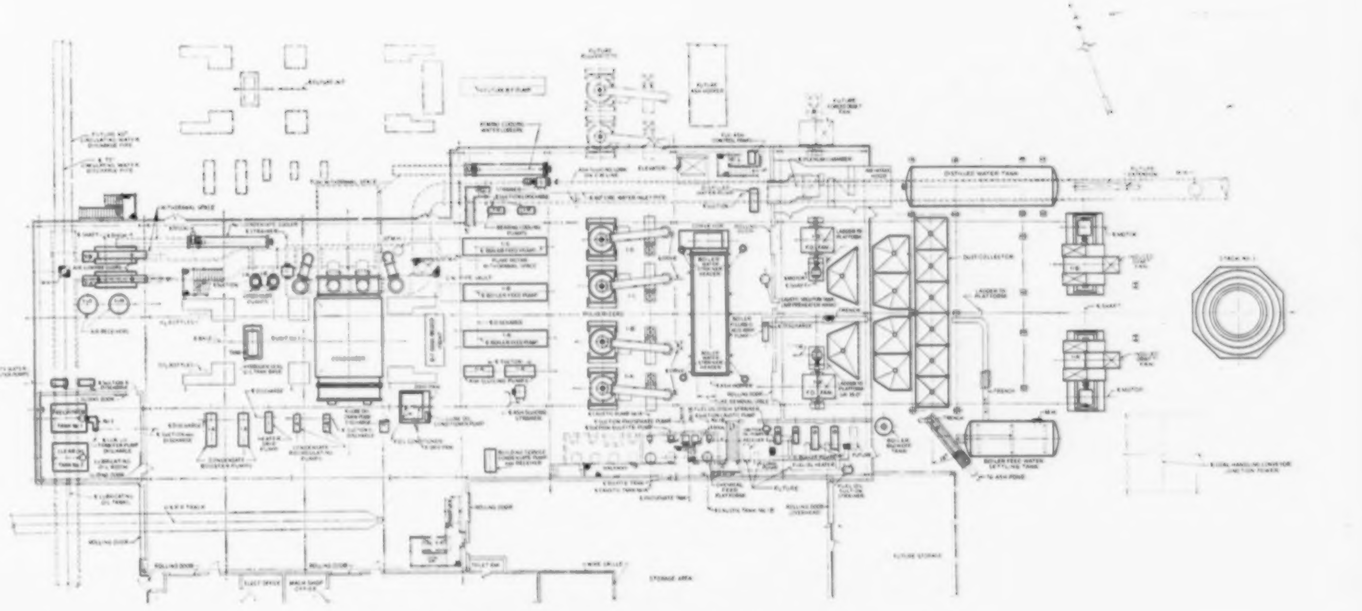
By D. P. HARDY

Station Superintendent

Virginia Electric and Power Company

LOCATED on a 300-acre tract of land on the Southern Branch of the Elizabeth River at the mouth of Deep Creek in eastern Virginia, the Portsmouth Power Station is the third steam generating station constructed by the Virginia Electric and Power Company in the Hampton Roads area. The first unit, which went into commercial operation this past May, has a capability of 105,000 kw and provides sufficient power to supply the needs of Portsmouth and a good part of Norfolk. Its output supplements that of the 160,000-kw Reeves Avenue Station in Norfolk and the 32,000-kw station in Hampton. All of these stations are tied together by high-voltage transmission lines which interconnect with other steam stations at Richmond, Alexandria, Bremo, Chesterfield and Possum Point, Virginia, and Ronceverte, West Virginia, and 16 hydro stations located within the Company's service area.

The site selected for the plant was chosen because of the advantages it offered in the way of fuel availability and transportation, cooling water supply, transmission line facilities and load growth. Since the station property is on the main line of the Norfolk and Western



Plan view of equipment at basement floor

Railway, a leading coal carrier, and is located within the switching limits of Norfolk, coal is available from several sources. The Elizabeth River not only furnishes condensing water but also provides access for large tankers to discharge fuel oil directly to oil-storage facilities now being constructed. Two 110,000-volt transmission lines connecting the Reeves Avenue Station in Norfolk and Suffolk, to the west, cross the property on which the station is built. The combination of immediate access to transmission lines and the unusual load growth in the Hampton Roads area added to the attractiveness of the location.

The initial installation consists of a 90,000/99,000-kw Preferred-Standard reheat turbine-generator and a 750,000 lb of steam per hour controlled-circulation steam generating unit. In laying out the station provision was made for an ultimate development to six units. A second boiler-turbine-generator unit is now under construction, substantially duplicating the first unit.

Building and Structures

Before the start of construction a pattern of soil-exploration borings was made to determine subsurface conditions. It was found that piling would be required to support the structures and equipment within the limits of permissible settlement. To avoid deep work under water, creosoted timber piles were used. Piles for the power-plant area were driven to sand strata approximately 40 ft below mean sea level and were designed to support a combined live and dead load of 18 tons each. To avoid the need for flood protection the ground floor of the plant was placed 12 ft above mean sea level.

In locating the station on the property site, an attempt was made to minimize foundation costs. Due consideration was also given to the effect of this location upon such items as circulating-water piping and the coal-handling system.

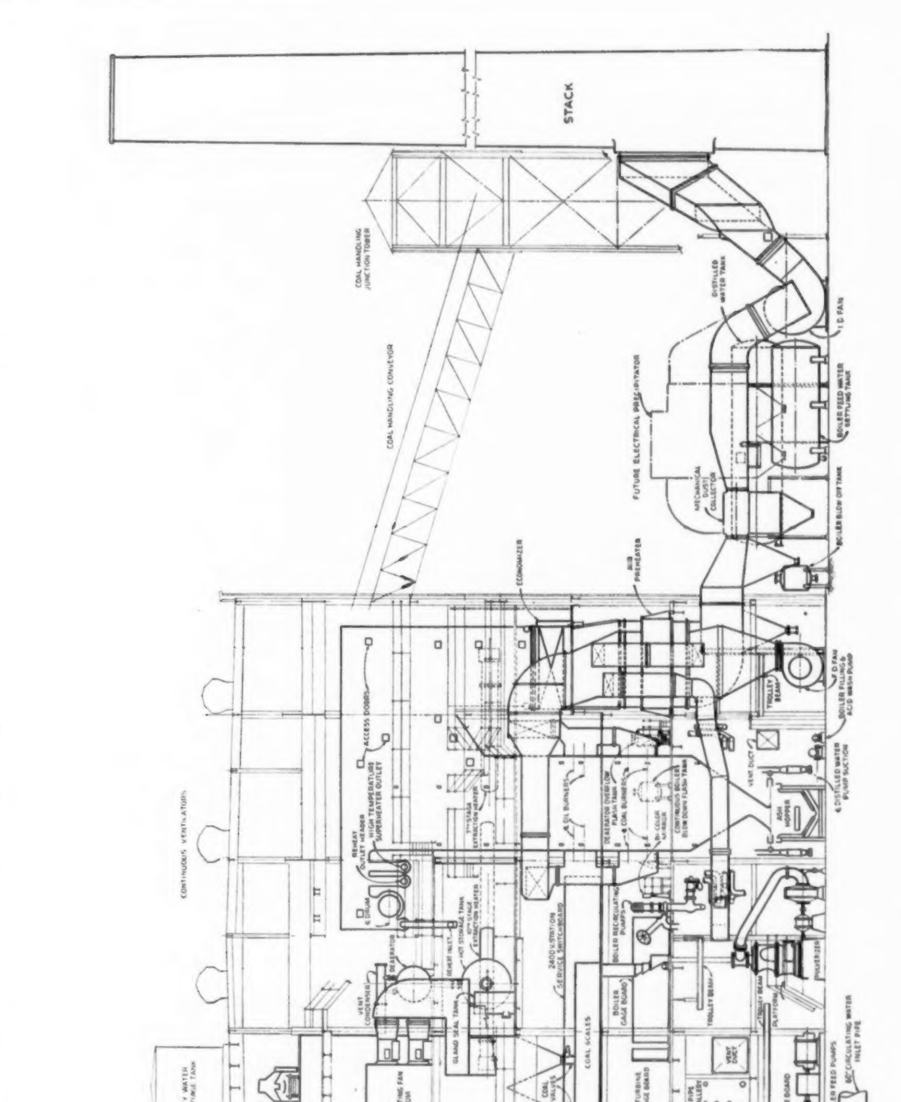
The power-plant-building structure encloses most of the equipment except for the induced-draft fans and dust collectors which are located outdoors. There is a temporary end to facilitate future construction and a permanent end to which is attached an administration building, including storeroom, shops, offices and laboratory. The structure consists of steel framing, reinforced-concrete floors, grating platforms and walkways, precast concrete roof and corrugated asbestos siding. Interior partitions are of concrete block or brick, except for some portions of the administration building, where semi-portable partitions of flat asbestos board are used.

Steam Generating Unit

The controlled-circulation type steam generating unit has double water-cooled furnaces. It has a continuous rating of 750,000 lb of steam per hour at superheater outlet conditions of 1500 psig, 1000 F with reheat to 1000 F. The superheater consists of two sections with desuperheating nozzles between the primary and secondary sections for emergency control of steam temperature beyond the range of the tilting burners. The reheater consists of one section with desuperheating nozzles for emergency steam-temperature control.

An economizer and two regenerative-type air preheaters are installed. Of the three motor-driven boiler circulating-water pumps two are required for normal operation. Four bowl-mill pulverizers are provided, three being required to produce rated steam output with a good grade of coal. The coal piping from the pulverizers to the burners is so arranged that one mill supplies coal to two burners in diagonally opposite corners of each half of the furnace, making a total of four burners for each pulverizer. Individual coal feeders located on the operating floor supply fuel to the pulverizers.

A system of automatic sequential, air-actuated, steam soot blowers is provided for cleaning the boiler, superheater and reheater surfaces and also for steam blowing and water washing of air-heater elements. There is a continuous blowdown connection on the boiler drum which is normally used to control boiler water concentration. Provision is made for acid cleaning of the boiler, including a steam-jet water heater and special pump for filling and emptying the boiler and circulating the acid solution.



Cross-section of station

Draft System

The two forced-draft fans are of the constant speed type, each capable of supplying 131,000 cfm of 80 F air at 11 in. static pressure. Each fan has vane control and outlet dampers and is driven by a 250-hp motor.

Induced-draft ducts from the air-heater outlet to the mechanical dust collector to the induced-draft fans, and thence to the 175-ft radial-brick stack, are of the welded type, fully insulated. Provision has been made for a future steam air heater and a bypass duct for use when burning fuel oil for extended periods of time.

The two induced-draft fans each handle 198,000 cfm of gas at 300 F at 15 in. static pressure. Each fan has vane control and inlet and outlet dampers and is driven by a 700-hp motor.

An interlock system establishes the sequence of starting the equipment connected with the boiler and assures that the equipment will be started in the correct sequence. The two induced-draft fans, two forced-draft fans, pulverizers, feeders and oil-burning equipment are interlocked electrically so that the following sequence takes place when starting the unit:

1. Induced-draft fans
2. Forced-draft fans
3. Pulverizers
4. Oil burners
5. Coal feeders

In case of failure of both induced-draft or forced-draft fans the vanes and dampers open wide and fuel feed is is cut off.

Feedwater System

Feedwater flows from the condenser to one of two vertical condensate pumps, through the inter- and after-condenser of the air-removal equipment, and through the hydrogen and lube-oil coolers to one of two booster pumps which delivers the water through the 19th and 17th-stage closed heaters to the 14th-stage deaerator. Water then flows to two of three boiler feed pumps which deliver the water through the 10th and 7th-stage closed heaters to the economizer.

The 19th and 17th-stage heaters are suspended vertically from the turbine room floor. The deaerating heater is of the horizontal type with separate heater and storage sections. Designed for 80 psig, it is capable of heating and deaerating 552,000 lb of water per hour. Both the 10th and 7th-stage heaters are of the horizontal type and are arranged so that the shell can be removed.

Each of the two motor-driven condensate booster pumps is capable of handling 617,000 lb per hr of 110-F water against a discharge head of 420 ft, with a suction head of 65.5 ft. Motor control is from the boiler feed gage board, and electric interlocks with the main condensate-pump motors insure that failure of a condensate pump will also trip a booster pump.

There are three boiler feed pumps, each capable of handling 440,000 lb per hr of 312-F water against a TDH of 1683 psig. The feedwater level control system controls drum water level automatically by varying the speed of the pumps through hydraulic couplings.

Water Treatment

Water for domestic and boiler plant use is obtained from the water system of the city of Portsmouth through an eight-inch line. The water main entering the plant supplies a 100,000-gal tank located at ground level. Another connection enters the plant and supplies two booster pumps which transfer the water into a 25,000-gal

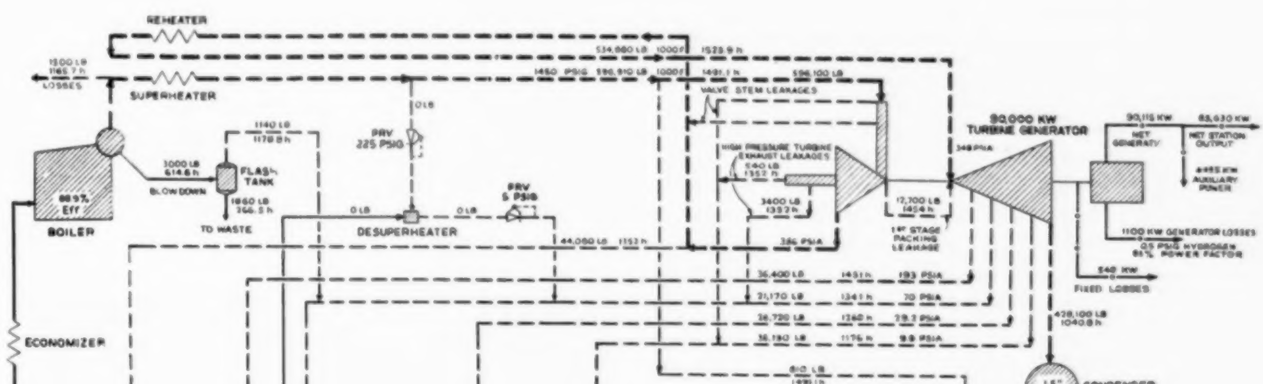
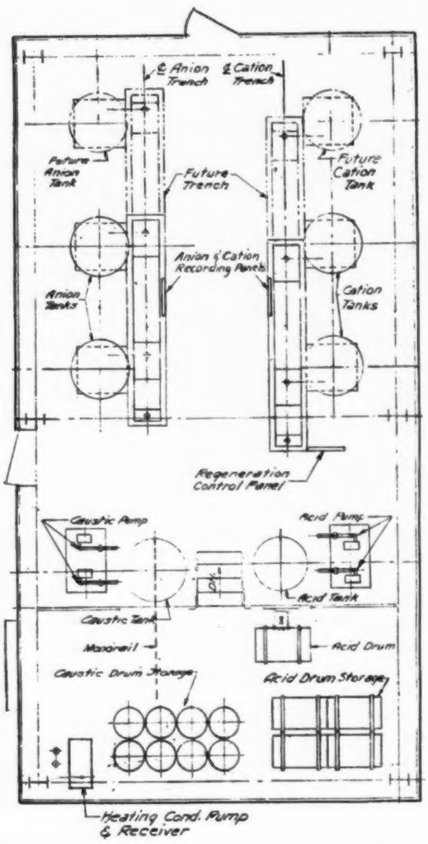


Diagram of heat balance at rated load



Arrangement of demineralizing plant

tank located on the boiler house roof. Lines from this tank provide water for domestic and boiler plant use.

A one-story building located outside the station houses the demineralizing plant for boiler feed makeup. The equipment includes two cation exchange units, two anion exchange units, regenerating equipment, tanks, controls and accessories necessary to produce 48,000 gal per 20-hour day of demineralized water from the city supply. The water from the demineralizing system is piped to the distilled water tank; a manual-operated valve is installed close to the tank for control of flow in accordance with station requirements.

Controls for the acid and caustic pumps are located in the water treating plant. A two-point conductivity recorder is installed on the discharge line from the demineralizing equipment. The recorder operates a solenoid valve in the discharge line which remains closed until the unit is properly rinsed and the effluent is satisfactory for boiler use.

Provisions for Station Controls

There are three main gage boards for plant operation. The boiler gage board includes the steam-temperature control system, combustion control, drum-water-level control, distilled-water-pump control and boiler-circulating-pump control. The steam-temperature control is of the electric type and tilts the burners and controls spray desuperheaters in order to maintain constant primary and reheat steam temperatures over a range of 520,000 to 750,000 lb per hr. The controls are in duplicate, one set being required for each side of the furnace. On the pneumatic combustion-control system, selector valves allow for manual or automatic operation of the system as a whole or individually for certain components.

The boiler-feed gage board includes control switches for circulating-water pumps, circulating-water air-removal pumps, condensate pumps, condensate-booster pumps, condensate-recirculating pumps, condensate-cooler pumps, distilled water pump, and boiler-feed pumps.

Located on the turbine gage board are control switches for condensate-recirculating pumps, auxiliary-turbine oil pumps, turning-gear oil pump, turning-gear motor, turbine lead valve and seal oil pumps.

Coal-Handling System

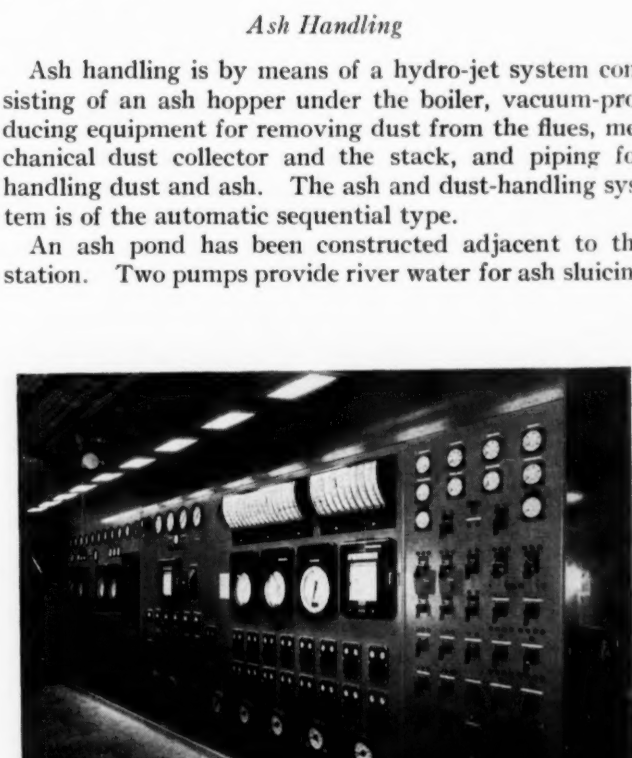
Coal is delivered to the station in coal cars which are discharged into a double-track hopper. From this point it is drawn at a uniform rate by a double-element reciprocating feeder and delivered to two successive belt conveyors, the latter of which is equipped with a weightometer and a magnetic-head pulley for removing tramp iron. Then the coal is delivered either to a hammer-mill crusher or a bypass chute. It is then conveyed to the station bunkers or to a storage pile in the yard. From the initial pile, coal is stocked out over the yard area beyond the railroad tracks; it can be reclaimed from this area by bulldozer and scraper equipment. Provision has been made for the future installation of a duplicate set of track hoppers with their respective feeders for receiving coal on a track to the south of the initial hopper.

The coal to be handled normally is either run-of-mine or slack bituminous coal weighing approximately 50 lb per cu ft coming from West Virginia districts. Each of the units in the initial installation operates at a speed that gives a capacity of 250 tons per hour for the complete system.

Ash Handling

Ash handling is by means of a hydro-jet system consisting of an ash hopper under the boiler, vacuum-producing equipment for removing dust from the flues, mechanical dust collector and the stack, and piping for handling dust and ash. The ash and dust-handling system is of the automatic sequential type.

An ash pond has been constructed adjacent to the station. Two pumps provide river water for ash sluicing



Control panel for boiler

Unusual view looking down on turbine-generator

to this pond. Each of the motor-driven pumps is capable of handling 1800 gpm of 60-F water against a TDH of 400 ft.

The fly-ash collector is of the mechanical, multi-unit centrifugal type arranged to remove 85 per cent by weight of fly ash from 360,000 cfm of flue gas at 300 F with a maximum draft loss of 3.0-in. water. It is installed outside the plant in the flue-gas ducts between the air heaters and the induced-draft fans. The collector hoppers are arranged for connections to the pneumatic dry ash removal system, and provision is made for possible future installation of an electrostatic precipitator.

Turbine-Generator

The turbine-generator is a 90,000/99,000-kw AIEE-ASME Preferred-Standard unit. The turbine is a 22-stage, 3600-rpm reheat machine designed for a throttle steam pressure of 1450 psig, 1000/1000 F, with an exhaust pressure of 1.5 in. Hg abs and with five extraction points for feedwater heating. The generator is rated at 90,000 kw, 0.85 power factor, 14,400 volts, three phase, 60 cycles, 3600 rpm and is equipped with a gear-connected exciter. It is provided with a hydrogen-cooling system designed for operation at full rated load at $^1/_2$-psig hydrogen pressure, 115 per cent rated load at 15-psig hydrogen and 125 per cent rated load (132,353 kva) at 30-psig hydrogen with 0.85 power factor lagging.

Steam from the boiler is admitted to the turbine through an emergency stop valve and then to the two control-valve chests located about midway down the high-pressure shell. The steam flows through the control valves and travels toward the front end of the machine, expanding through seven stages. This steam is then reheated in the boiler and comes back to the turbine after first passing through an intercept valve. There are four openings in the high-pressure shell just back of the control-valve chests where the reheat steam enters the turbine and expands through the rest of the stages of the machine.

Condenser

The condenser is a 65,000-sq ft, two-pass, split-water-flow unit designed for downflow of condensing water. Air-removal steam jets with inter- and after-condensers, a hogging jet and vertical condensate pumps are included. The two condensate pumps are capable of handling 1250 gpm each against a TDH of 131.5 ft. During times of high-river-water temperature and heavy generating unit loads, it is necessary to cool the condensate before passing it through the hydrogen and oil coolers. For this purpose one condensate cooler and two motor-driven condensate-recirculating-water pumps are provided. The circulating-water piping at the condenser is arranged

Circulating-water disharge canal

Crusher house

with 30-in. butterfly valves for use when the condenser is being backwashed.

Circulating-Water System

The circulating-water system consists of a screen-well house with two traveling screens. Two circulating-water pumps with constant-speed motors are installed; they are rated at 30,000 gpm at 35 ft TDH. Motor-operated butterfly valves at the pump discharge are interlocked with the pump motors. All of the circulating-water piping in the yard is concrete with the exception of cast-iron pipe at the circulating-water pumps. Inside and under the turbine room it is cast-iron bell and spigot, or flanged as required. The 72-in. circulating-water discharge piping is sized to handle two 100,000-kw units and empties through a seal pit into an open ditch which is 45 ft wide and extends 780 ft to the river.

Electrical Features

The generator output at a potential of 14.4 kv is delivered to a 110-kv outdoor substation through metal-enclosed isolated-phase generator leads to a bank of two three-phase, 67,500-kva transformers which are connected in parallel and located outdoors. These transformers are oil insulated and are provided with forced air-oil cooling equipment. The transformer bank is connected to the substation high-tension bus through oil circuit beakers having an interrupting capacity of 3,500,000 kva.

A three-phase station-service transformer having a capacity of 7500 kva has been provided for stepping down generator voltage of 14.4 kv to 2.4 kv. A three-phase reserve station transformer of 6000-kva capacity enables the transmission line voltage of 110 kv to be stepped down to 2.4 kv. This transformer is located outdoors and is connected to the 110-kv Suffolk line oil-circuit-breaker bypass connection through a pole-top disconnecting switch.

The 2.4-kv switchgear is located on an intermediate floor in the boiler room. All motor-driven boiler auxiliaries rated at 150 hp and larger are supplied direct from this switchboard. A 460-volt station service unit substation is fed from the 2.4-kv board. All motors 100 hp and smaller with the exception of the turbine auxiliary oil pump are supplied from this substation. A control storage battery has been provided for direct-current control for the various switchboards and panels, emergency lighting, direct-current valve motors and emergency bearing lubricating-oil pump.

Table of Principal Equipment

Steam generating equipment, including pulverizers	Combustion Engineering, Inc.
Ljungstrom air preheaters	Air Preheater Corp.
Radial brick chimney	Custodis Construction Co., Inc.
Forced-draft fans	Sturtevant Division, Westinghouse Electric Corp.
Induced-draft fans	Green Fuel Economizer Co., Inc.
Combustion control equipment	Bailey Meter Co.
Duct work	Connery Construction Co.
Centrifugal-type fly-ash collector	Western Precipitation Corp.
Boiler-feed pumps	Ingersoll-Rand Co.
Fluid drive for boiler-feed pumps	American Blower Corp.
Deaerator	Worthington Corp.
Closed feedwater heaters	Griscom-Russell Co.
Distilled water pump	Worthington Corp.
Level and temperature control equipment	Swartwout Co.
Condensate booster pumps	Ingersoll-Rand Co.
Condensate cooler	Griscom-Russell Co.
Condensate recirculating pump	Worthington Corp.
Heater drip pump	Ingersoll-Rand Co.
Demineralizing plant	Cochrane Corp.
Chemical feed equipment	Milton Roy Co.
Surface condenser	Ingersoll-Rand Co.
Condenser circulating-water pumps	Ingersoll-Rand Co.
Traveling water screens	Chain-Belt Co.
Chlorine control equipment	Wallace & Tiernan Products, Inc.
Butterfly valves	Henry Pratt Co., Inc.
Piping system	National Valve and Mfg. Co.
High-pressure valves	Atwood & Morrill, Chapman, Walworth
Low-pressure valves	Ohio Injector, Jenkins Bros., and Manning, Maxwell & Moore
Miscellaneous tanks	Richmond Engineering Co., Inc.
Pressure-reducing station	Swartwout Co.
Steam traps	Armstrong Machine Works
Coal scales	Stock Equipment Co.
Coal-handling equipment	Link-Belt Co.
Coal crusher	Pennsylvania Crusher Co.
Ash-handling equipment	United Conveyor Corp.
Shake-out equipment	Allis-Chalmers Mfg. Co.
Car pullers	Stephens-Adamson Mfg. Co.
Fuel-oil pump	Turbine Equipment Co.
Fuel-oil storage tank	Graver Tank & Mfg. Co.
Turbine-generator unit	General Electric Co.
100-ton traveling crane	Manning, Maxwell & Moore, Inc.
Main power transformers	Westinghouse Electric Corp.
Station service transfer	Pennsylvania Transformer Co.
Station service switchboard	Allis-Chalmers Mfg. Co.
Gage boards	G & N Engineering Co.
Consulting engineers and constructors	Stone & Webster Engineering Corp.

ASME Holds Semi-Annual Meeting at Los Angeles

FROM June 28 through July 2 The American Society of Mechanical Engineers held its 1953 Semi-Annual Meeting at the new Statler Hotel in Los Angeles with a varied program covering a diversity of subjects and approximately 125 technical papers.

At the President's Luncheon on Monday, President **Frederick S. Blackall, Jr.,** spoke of the advantages of membership in the ASME. It affords an opportunity, he said, for one to grow in stature and to contribute to the advancement of the profession. Specialized work on committees should not, however, permit an individual to lose sight of the whole picture of what the Society is doing for the welfare and standing of the engineering profession.

Moreover, managers of enterprises in the engineering field should not drop their interest in technical matters, nor permit their memberships to lapse when they reach that level, as the Society is continually doing much for the younger technical men in their organizations. Even though a man at the management level may lack qualifications for regular membership, the affiliate grade is open to him. In fact, the various ASME codes and standards fully justify his interest in and support of the work of the Society.

Report of Nominating Committee

The Nominating Committee reported the following list of officers for 1953–1954 which will be submitted to the entire membership in September for letter ballot.

President: **Lewis K. Sillcox,** vice chairman of the Board, The New York Air Brake Co.

Regional vice presidents:[1]

Region I—**Willis F. Thompson,** vice president of Westcott & Mapes, Inc., New Haven, Conn.

Region III—**Prof. W. G. McLean,** Lafayette College, Easton, Pa.

Region V—**Thompson Chandler,** Carbide & Carbon Chemical Corp., South Charleston, W. Va.

Region VII—**Vernon A. Peterson,** Elliott Co., Los Angeles, Calif.

Region VIII—**Prof. C. H. Shumaker,** Southern Methodist University, Dallas, Tex.

Directors-at-large:

Frank L. Bradley, mechanical engineer, Forstmann Woolen Co., Passaic, N. J.

Robert B. Lea, Sperry Corp., New York, N. Y.

The place and date of the 1954 Semi-Annual Meeting was announced as Pittsburgh, Pa., June 20–24, with headquarters at the William Penn Hotel.

At the Business Meeting it was voted to approve a proposed amendment to the Constitution to alter the present grades of membership, changing that of Junior to Associate and Associate to Affiliate, with upward qualifications in each grade. This proposal will later be submitted to the entire membership for letter ballot.

[1] Vice presidents for Regions II, IV and VI are not elected this year.

Scientists and Engineers Defined

As the principal speaker at the banquet, **Dr. L. A. DuBridge,** president of California Institute of Technology, attempted to define the rôles of scientists and engineers, and their relation to the finer things of life.

The aim of the former, he pointed out, is to enlarge man's understanding of the physical world. In this they are motivated by a sense of curiosity or urge to explore and conquer ignorance.

The engineer, on the other hand, seeks to apply the products of scientific research to development of methods for satisfying human needs. This has resulted not only in essential progress but also many gadgets which we have come to accept as necessary in the pursuance of everyday life. However, Dr. DuBridge cautioned that many of these gadgets, of which we are proud and often brag, may not be acceptable to the peoples of certain foreign countries whose standards of values differ from ours.

Again, the work of scientists and engineers in some respects has led to problems in public relations and understanding, with the result that in some circles they unfortunately are looked upon as inventors of diabolical weapons of death. Here the existence of the thing has overshadowed the purpose for which it was developed in meeting human needs.

While maintenance of a healthy science and technology is largely a matter for private enterprise, universities and foundations, the stake of the government is so great that it cannot shirk its responsibility. In this respect, Dr. DuBridge cautioned against the current trend toward reduction in the research budgets of government agencies.

Removing Slag Accumulations

The program of the first Power Session dealt with the problem of slag accumulations on boiler heating surfaces. The first of three papers, by **L. B. Schueler** of Diamond Power Specialty Corp., covered the principles governing the external cleaning of direct-fired heat-transfer surfaces, together with equipment and operating methods involved. The second paper, under the title "Removal of Fireside Deposits Through Use of Mechanical Slag Blowers," was by **J. A. Vanyo, Jr.,** and **S. F. Walleze** of Copes-Vulcan Division, Continental Foundry & Machine Co. The third paper was "Application of Additives to Fuel Oil and Their Use in Steam Generating Units," by **J. B. McIlroy** and **E. J. Holler, Jr.,** of Babcock & Wilcox Co., and **R. B. Lee** of Florida Power Corp.

The problem today, Mr. Schueler pointed out, is to provide a boiler cleaning system rather than an aggregate of soot-blower units. Large coal-fired units operating at high continuous rating with high-ash coals present a cleaning problem which may call for (1) furnace-wall cleaning every 2 to 4 hr; (2) boiler-screen cleaning every

4 to 8 hr; (3) convection bank cleaning every 8 to 12 hr; (4) air heater cleaning every 12 to 24 hr; and (5) employment of blowing pressures of 250 to 100 psig in the rear portion of the unit where dust is involved.

In the case of oil-fired plants burning currently available fair and poor grades of oil, (1) there need be no furnace-wall cleaning; (2) the boiler screen should be cleaned every 12 to 24 hr; (3) the convection bank every 8 to 12 hr; and (4) the air heater every 24 hr. Blowing pressures range from 250 psig in the screen and air heater to 150 psig in the rear banks.

There will be exceptions to the foregoing recommendations, depending on extremes in rating and in fuel qualities. With very poor oil it may be necessary to employ periodic water washing.

It was the author's opinion that the cleaning of tubular and regenerative air heaters is best accomplished with air as the blowing medium, with superheated steam next and saturated steam a poor third. The recent trend toward low final gas temperature leaving the air heater, below about 300 F, coupled with cooler inlet air (particularly in outdoor stations) has resulted in severe cases of plugging and corrosion at the heater outlet.

With reference to the employment of pellets projected at high velocity by compressed air for cleaning external surfaces, Mr. Schueler was of the opinion that such measures, although not too certain as yet, give promise for use under severe conditions where steam, air or water have proved ineffective. That is, they seem to be indicated for infrequent use where deposits are such as to threaten a forced shutdown for manual cleaning.

The second paper, by Messrs. Vanyo and Walleze, dealt particularly with oil-fired boilers operating at pressures above 600 psig, inasmuch as the slagging patterns in coal-fired installations are more predictable and the slag is less tenacious than that formed with the lower grades of fuel oil. The troublesome fuel oils usually have an ash content ranging from 0.03 to 0.25 by weight, which runs high in compounds of sodium, vanadium, iron and nickel. Also, sulfuric anhydride and sodium oxide are known to be present in large quantities.

Of fifty stations included in a recent survey, the consensus was that although the slag accumulation rate and density of the slag varies directly with the ash content of the oil, the initial accumulation varies proportionately with the percentage of sodium sulfate present, this being formed by sulfuric anhydride and sodium oxide or sodium chloride and sulfur in the process of combustion. This action is believed to be due to the bonding of the oxides of sodium, vanadium and iron with sodium sulfate, which is water insoluble and acid reacting. The adhesion to the tubes is apparently dependent on the percentage of sodium sulfate present.

In many of the plants surveyed hand-lancing ports had to be installed in order to remove deposits that soot blowers, as installed, would not reach. Use of fuel additives provided varying degrees of relief.

Plotting of slag accumulation against time showed the initial accumulation to be comparatively slow, but once it had formed the curve rose sharply until the tubes were bridged over.

Attempts at filtering the oil did not prove successful, inasmuch as the percentage of oil-soluble ash in oils is high. Moreover, the theory advanced by some that residuals could be removed from the oil by centrifuging has not been tried out on a plant-size scale, although it is showing some encouragement in laboratory tests.

Painting the tubes with lime slurry during boiler outage and continuation of the addition of a high pH solution in an effort to keep the tube surfaces alkaline has met with some success in delaying the initial accumulation of slag.

With reference to use of mechanical slag blowers, the authors pointed out that fixed-position rotary soot blowers are not effective in removing fireside deposits in radiant sections. Here the long retractable slag blower is not only effective but, if properly applied, possesses an economic advantage over hand lancing.

With a retractable type of slag blower, steam, air or even water may be used. The effective cleaning distance with such a blower is from 4 to 10 ft, depending on its design, the blowing pressure and the deposits to be removed. Ordinary coal slag responds to nozzle pressures as low as 125 psig, but 200 psig is usually considered better, and in some cases even higher pressure may be necessary.

With further reference to selection of the blowing medium for a retractable type slag blower, the paper took issue with the idea that air is less likely to cut tubes than steam, inasmuch as it is the abrasive entrained ash that does the damage rather than the blowing medium, except in the case of extremely high velocity water.

The paper on "Application of Additives to Fuel Oil" by Messrs. McIlroy, Holler and Lee was originally presented at the 1952 Annual Meeting in New York (see report of Meeting in December 1952 COMBUSTION). This paper related experience at the Inglis Station with a 300,000-lb per hr, 900-psig, 950-F boiler where additives in powdered form were mixed with the heated fuel oil. As additives, both dolomite and alumina were found to be effective in replacing a hard adherent deposit by a powdery ash that could be readily removed by air lancing.

Of the two, dolomite was the more effective in reducing the vanadium content of the ash, whereas alumina caused a greater reduction in sulfur and raised the fusion temperature of the ash to a higher value. However, the dolomite is much cheaper.

Discussion

One discusser pointed out that when burning oil slagging usually occurs below 1600 F and deposits on superheaters and reheaters generally extend around the tubes. Blowing schedules are required which prevent build-up of the ash. Good results may be obtained by adding a small amount of water to the steam on a day-to-day basis, thus avoiding periodic heavy water lancing such as may be necessary if a heavy build-up is permitted.

Another discusser stressed the importance of a program of protective maintenance and the keeping of complete records pertaining to blowing and surface conditions. This has become especially desirable as oil fuel continues on the downgrade.

The opinion was expressed by one speaker that the long retractable blower is the most effective means of removing oil slag, if properly applied. Rotative and traversing speeds were considered very important for optimum results. The more tenacious the slag, the

more effective is slower speed. Since slag accumulations accelerate rapidly, once the initial deposit has occurred, it becomes most important to prevent a rapid rise in the thickness of such deposits.

The relative merits of steam and air as blowing mediums still appear to be a question; also electric versus air control. Plans are being made for a study of two identical boilers in the same plant, one equipped with air and the other with steam blowing.

Since a very large boiler may involve up to as many as a hundred blowers, in such a case electric controls may prove less expensive, especially since air controls would require large compressor capacity.

For cleaning air-preheater surfaces, either superheated steam or air is indicated—never saturated steam because of possibilities of corrosion.

Mr. Lee pointed out that since the paper on fuel-oil additives had been written, the Florida Power Corp. had developed a method of blowing the dolomite into the furnace between the burners in the front wall. This has resulted in reduced air-heater corrosion. A screw-feeder system is employed to handle the dolomite to the furnace.

At another station where Venezuelan oil, high in vanadium content, is burned both aluminum and dolomite were tried as additives. The latter reduced the air-heater corrosion and there was less slagging of boiler tubes.

It was mentioned that the General Electric Company has recently produced an additive formula for use in gas turbines which involves a calcium-vanadium ratio, it being found that vanadium is effective in controlling sodium corrosion.

Another discusser, representing an oil company, pointed out that the oils which refineries are forced to burn are of much lower grade than those generally marketed, and that the complexity of salts precludes the use of a single additive. He was of the opinion that there are many basic factors, such as tube spacing, flame shape, furnace conditions, etc., which, if corrected, might make the use of additives unnecessary.

Nuclear Power

R. A. Bowman of the Bechtel Corporation in a paper entitled "Features of Nuclear Power Plants of Interest to Power Plant Engineers and Operators" outlined some of the operating problems that he envisioned would be associated with a nuclear power plant. A stack will be required in a nonfuel burning type plant in order to dispose of gases containing moderate amounts of radioactivity, and normally ventilating air will be continuously discharged to this stack as a precautionary measure. The author felt confident that nuclear plants could take load swings as well as conventional plants and believed that the limiting rate of load change would be set by the turbine and not by the reactor nor by the steam generator.

The basic control system is expected to resemble the familiar three-element combustion control,- with the prime signal originated by the steam pressure and the secondary from a steam-flow element. These signals will be balanced against a reactor output signal produced by neutron flux meters in the reactors. Imbalance will cause servo mechanisms to move the control rods so that the reactor output will balance the turbine demand.

The steps involved in refueling a nuclear power plant were set forth in considerable detail. Also Mr. Bowman explained some of the steps necessary to insure protection of the operating personnel.

Discussion

There were several discussions of Mr. Bowman's paper, among which the following points were raised:

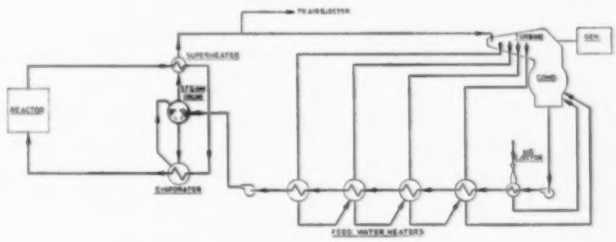
1. Probabilities are that nuclear power plants will be base loaded because of the relatively low-cost fuel.

2. Although it is possible to stop the fission process readily in a reactor, heat liberation will continue and it will therefore be necessary to continue cooling after shutdown. Means must be found to absorb the heat from the reactor if the turbine is shut down.

3. Use of sodium as a heat-transfer medium is favored because it does not absorb many neutrons and possesses excellent heat-transfer properties. It boils at 1600 F and freezes at 200 F, but care must be taken that it does not come in contact with water, for it will burn if it does.

4. Refueling of a reactor will present a problem and will require complete shutting down of the unit.

5. There is no danger of a reactor exploding, but it might melt if it should get out of control, and also liberate dangerous radiation.



Basic flow diagram for a nuclear power plant

6. The standards of purity of the boiler water may have to be raised.

7. Safety-valve discharge and blowdown may present a problem from the radioactive viewpoint.

8. Nuclear-energy power-generating units will need to be large to compete with conventional units; there is some question as to whether very large units can be served by a single reactor. Hence, it was suggested that package-type reactors might stand a better chance of meeting the requirements of central stations.

9. Since the reliability of reactors remains to be determined, one speaker questioned whether the risk investment by utilities could be justified.

10. Government-sponsored central-station pilot plants were suggested as an initial step.

Design of Steam Piping and Valves for 1100 F

Since the strength of materials tends to decrease with temperature, most steels suitable for service at lower temperatures, do not possess sufficient strength at 1100 F to sustain the requisite loads for long periods without

rupture, or at least excessive deformation. This tendency for strength to decrease with temperature demands a corresponding increase in pipe wall thickness in order to keep stresses within safe limits. Moreover, there are additional characteristics that demand consideration, such as corrosion resistance, immunity to graphitization, stability of carbides, soundness of manufacture, and adaptability to fabrication, including upsetting, bending and welding.

At present there is only one high-pressure installation in operation at 1100 F and this employs austenitic steel for the high-temperature piping. However, austenitic steels are definitely expensive and the alloying elements, particularly nickel and columbium are in short supply at the present time.

In a paper which reviewed existing research data on the behavior of austenitic and ferritic steels with steam at 1100 F, including stresses assigned by Code committees, **Frank A. Ritchings** and **Sabin Crocker,** both of Ebasco Services, suggested that low-alloy ferritic steels might be made to serve the purpose. Before doing so on an extensive scale, however, they recommended that a trial installation be made in which the 1100-F steam piping would consist, in whole or in part, of low-alloy ferritic steel.

The authors gave the following reasons for favoring ferritic steel piping where throttle temperatures are 1100 F:

1. Cost.—Pound for pound, austenitic steel costs in the order of four to five times that of low-alloy ferritic steel, although when considered in terms of cost per foot this premium is reduced considerably.
2. Conservation of Strategic Materials.—During the present emergency the nickel and columbium or titanium components of austenitic stainless steels must be conserved for essential use.
3. Corrosion.—The low-chromium ferritic steels seem sufficiently corrosion-resistant to warrant their use at 1100 F.
4. Welded Joints.—Austenitic steels are difficult to weld without producing cracks in the deposited metal. Such welds and the adjacent heat-affected zones lack stability of the carbides unless "stabilized" with columbium or titanium, and are more susceptible to embrittlement than ferritic welds under prolonged exposure to high temperature.

Discussion

In the discussion of this paper it was urged that more attention be given to high-temperature fatigue, especially as hot piping reactions may throw equipment out of line. It was further contended that satisfactory austenitic weldments are now not difficult, nor welds between dissimilar metals; but the advisability of making such welds in the shop rather than in the field was stressed. Furthermore, such welds should be made between sections of pipe and not between pipe and fittings.

Preference was shown for the higher alloy material by one discusser who cited a very high-pressure, high-temperature installation in which the main steam is carried by two cross-connected $10^1/_2$-in. leads at 1500 fpm velocity rather than employing a single large pipe. Difficulties in welding dissimilar materials increase with pipe diameters.

Fabrication of Austenitic Stainless Steel Steam Piping for 1100 F

W. G. Benz and **R. H. Caughey** of M. W. Kellogg Company presented a paper on the above subject in two parts. The first gave the results of a metallurgical investigation leading to welding recommendations and heat-treating procedures for austenitic, type 347 (18 per cent Cr, 10 per cent Ni-Cb) stainless steel steam piping for operation at 1100 F. The second part reviewed shop fabrication of piping assemblies of this material. Particular reference was made to two central stations employing, in part, butt-welded stainless steel piping of this type. The first of these stations has been in service (turbine piping only) about four years at 1050 F. One unit of the second station was recently placed in service with the main steam leads operating at 1100 F.

In the first installation cited, after about a year's service a limited amount of cracking was experienced in the parent metal adjacent to weld joints. This, however, was attributed to component design and improper supports. When these were corrected to remove stress concentrations and lower the primary stress ranges, no further cracking occurred.

Since the second installation involves the highest temperature and pressure used to date in a commercial generating station in this country, it was considered appropriate, prior to installation, to re-examine the metallurgical and welding procedures formerly used for type 347 piping. This led to a joint investigation by the owners and the M. W. Kellogg Company.

Conclusions drawn from this investigation were as follows:

1. Ferrite bearing type 347 weld deposits should continue to be the practice in welding type 347 piping systems for use in electric generating stations. Continued studies toward the development of a satisfactory fully austenitic deposit are recommended.
2. Electrode composition should be balanced to produce deposits containing from 1–4 per cent ferrite.
3. Levels of certain elements in the deposit should be held within the following limitations:
   a. Per cent carbon—0.07 to 0.10.
   b. Per cent silicon—approximately five times the amount of carbon.
   c. Per cent columbium—0.60 to 0.90.
4. A postwelding solution heat treatment at 1950 F is recommended for type 347 piping operating at elevated temperatures. The recommended heat cycle for this treatment is:
   a. Heat rapidly to 600 F.
   b. 600 to 1100 F, heat at a rate not to exceed 300 F one hour maximum.
   c. Hold for two hours at 1000 to 1100 F.
   d. Continue heating from 1100 to 1950 F, a minimum rate of 600 F per hour.
   e. Hold at 1950 F for two hours.
   f. Air cool from 1950 F as rapidly and as uniformly as possible.

The second part of the paper, relating to shop fabrication, mentioned that as a result of the metallurgical investigation the fabrication procedure for stainless steel power piping was modified to specify the special low-ferrite type 347 electrode with a postwelding solu-

tion heat treatment at 1900 F. In addition, since K-welding had been used successfully to make the test joints for the investigation, the M. K. Kellogg Company was requested to fabricate both main steam and turbine lead assemblies with this process because high-quality, complete-penetration welds having a controlled inside contour can be made without the use of backing rings. This application of inert-gas-shielded arc welding, combined with a pressure-controlled inert-gas backup, was described in detail in a section on "Welding of Main Steam and Turbine Lead Piping."

Iron Oxide Deposits

In a paper entitled "Preliminary Investigation of Iron Oxide Deposition in Boiler Feedwater Systems," **E. G. Gothberg, H. Kehmna** and **E. S. Johnson,** of the Pacific Gas and Electric Co., presented a progress report on an investigation carried out at the Kern Steam Plant of their company. A serious problem was encountered with a 100,000-kw unit at this plant when the secondary boiler feedwater pumps lost up to 20 per cent of their capacity. The pump internals were coated with a black, hard, tenacious deposit which was thick enough to interfere with flow. Chemical analysis disclosed that the deposit was essentially a mixture of ferrous and ferric oxides, corresponding to about 90 per cent ferrous-ferric oxide (black magnetic oxide); 7 per cent ferrous oxide and a trace of metallic iron.

The plant consists of four steam generators of equal rating which are connected by a common header; two turbines, one rated at 75 mw and the other at 105 mw; common feedwater and main and auxiliary steam systems; and a condenser cooling water system employing cooling towers. Iron pickup is prevalent in various amounts throughout the feedwater, drip and steam systems. The larger amounts, based on the mechanical replacements required, appear to originate in the extraction heater drip lines. Modifications of chemical control were tried without finding a complete solution to the problem.

Based on their observations and analyses of plant operation, the authors conceived what they termed "a functional model as a basis for analytical discussion." In this concept they considered the feedwater system to be made up of three feedwater heaters and two sources of agitation, in the form of pumps, connected by lengths of iron pipe through which the feedwater solution flows. They then studied this relatively complex bypass network in terms of equilibrium conditions and the kinetics of the hydroxide deposit mechanism. Based on the latter they made the following verifiable predictions:

1. Deposition cannot be prevented, but the physical properties of the deposit can be altered to the extent that hard, strongly adherent deposits may be avoided.
2. Acceleration of the oxidation reaction in the low temperature region of the cycle before the occurrence of significant hydration will result in hardness deposits made up largely of ferric oxide.
3. Slowing of the oxidation reaction so that oxidation occurs in the higher temperature region results in deposits which are increasingly ferrous.

Investigations are being continued to arrive at more conclusive results. Work is being done on the catalysis of the oxidation reaction in the low-temperature regions, since it is believed that the chloride content of the condensate acts as a natural catalyst in some systems. Experiments are being conducted in which a definite sodium chloride concentration is maintained in the boiler water which will provide a small but not negligible sodium chloride concentration throughout the water cycle.

Reduction of Condensate-Line Corrosion

Scott Jensen of the Southern California Edison Company and **E. R. Lang** of Hall Laboratories, Inc., presented a paper under the above title in which they reported progress made in reducing iron and copper corrosion, using ammonia, cyclohexylamine and sodium sulfite at the Long Beach and Redondo Steam Stations.

There are seven boilers rated at 420,000 lb of steam per hr at 450 psig, 750 F at Plant No. 3 of the Long Beach Station, where deaeration is carried out in hotwells. Cyclohexylamine was first added in 1948, and a reduction of iron deposits in one boiler was observed. Because of a change in plant water supply which raised the pH of the condensate above 8.0, the addition of cyclohexylamine was discontinued. However, the amount of iron and copper deposits in the boilers increased, and consequently the feeding of cyclohexylamine was resumed. The effect of this, over a sixty-day period, was to reduce the iron in the condensate from 0.20 to 0.11 ppm; the copper, from 0.026 to 0.015 ppm; while the ammonia remained at 0.3 ppm and the pH at 8.7. At Redondo experience with the use of cyclohexylamine was similarly favorable and also made possible a reduction of 25 per cent in the amount of caustic feed, with consequent reduction in blowdown.

The authors offered the following conclusions:

1. In the systems investigated the major portion of corrosion occurs between the first point of condensation and the condensate-pump discharge.
2. Despite the presence of sufficient ammonia to maintain a pH of 8.5 at the condensate-pump discharge, corrosion of iron occurred in portions of the system immediately following the first steam condensation.
3. Batch feeding of cyclohexylamine once a day provided better protection to both iron and copper alloys than was afforded by the ammonia naturally present in the system.
4. Continuous feeding of cyclohexylamine along with sodium sulfite at the condensate-pump discharge still further reduced the iron and copper content of the condensate and boiler feedwater. Low levels of 0.02 ppm of Fe and 0.01 ppm of Cu in the condensate have been attained in two plants.
5. No increase in ammonia content of the condensate has been observed as a result of the continuous feed of cyclohexylamine to a boiler producing steam at 900 F.

Recirculating Cooling Water

J. H. Saunders of The Tucson Gas, Electric Light & Power Co. presented a paper entitled "Recirculating Cooling-Water System at Tucson."

The DeMoss Petrie Steam Plant contains two turbines

operating at 600 psig, 825 F, one rated at 12,500 kw and the other at 11,500 kw. Soon after these units went into service in 1949 trouble was experienced due to delignification of wood in the cooling towers and corrosion in the piping, condensers and water boxes. Corrosion in the piping of the bearing cooling system was partially overcome by the addition of sodium metaphosphate, together with a small amount of calcium salt. Although makeup water was originally zeolite softened, it was decided to use raw well water for makeup and to try acid treatment for the cooling water.

With the lower pH of the cooling water the delignification of the tower wood is greatly retarded and corrosion buildup in the condensers has been very substantially reduced. At the same time a substantial saving in cost (about 43 per cent less than with zeolite) has been made through use of the acid-metaphosphate treatment for the cooling-water system.

Turbine Economy

A. Keller and **J. E. Downs** of the General Electric Co. presented a paper entitled "Effect of Exhaust Pressure on the Economy of Condensing Turbines," the purpose of which is to provide quick and accurate methods of determining changes in heat rates or turbine capability resulting from exhaust-pressure changes. The methods are applicable to turbines of 25,000 kw and larger and should be useful for selection of alternate turbine designs and for sizing condensers.

Optimum exhaust pressure for a turbine operating with extraction to its feedwater heating cycle is defined as that pressure at the exhaust flange which will give the minimum heat rate when operating at constant throttle flow and initial and reheat steam conditions. At higher or lower exhaust pressures generation is less and the heat rate is higher due to the relation between the two effects, which is described as follows:

1. As exhaust pressure is lowered toward the optimum for nonextraction operation, the increase in available energy per pound of steam flow to the condenser results in a varying increase in used energy per pound, as determined by change in exhaust loss, with a resulting increase in generation.
2. Meanwhile the lower exhaust pressure and corresponding lower saturation temperature in the condenser results in lower condensate temperature entering the lowest pressure feedwater heater. Accordingly, additional steam is extracted from the turbine to this heater, causing a reduction in the steam flow through the later stages of the turbine, with a resulting loss in power generation.

Optimum exhaust pressure occurs at the point where these two effects are equal. At exhaust pressures lower than optimum, the increase in power generation due to (1) above is less than the decrease due to (2), so a net reduction in power generation and increase in heat rate results as exhaust pressure is lowered further. At exhaust pressures higher than optimum, a reduction in exhaust pressure will cause a greater increase in (1) than decrease in (2) with a net increase in power generation and decrease in heat rate.

The authors cautioned that the method is limited to the prediction of comparative heat rates, steam rates and kilowatt capabilities for different exhaust pressures. Economic evaluations of alternate turbine or condenser designs must be dealt with separately.

Corrosion in Moisture Region of Large Steam Turbines

In a modern 21-stage condensing turbine the so-called wet region will start at about the 14th or 15th stage at full load and continue to the exhaust, under which condition moisture increases up to 12 or 13 per cent. At very low loads the moisture at the exhaust may be as low as 8 or 9 per cent, and if the initial steam temperature remains constant the dewpoint will move two or three stages toward the front end. For example, over half a ton of water per minute may leave the last stage of a 60,000-kw condensing turbine, despite the use of stage drains. In a comparable reheat unit the moisture region includes only about the three last stages, so the corrosion problem is reduced.

This wet region is evidenced by anodic areas in nonchromium bearing metals, surrounded by large areas covered by a hard layer of products of corrosion. When a condensing turbine that is subject to such corrosion is first opened after a period of operation, bright metal is seen in the anodic areas and the crystalline structure of the metal is often evident to the naked eye. These areas are larger in regions of high liquid velocity with erosion becoming dominent in regions of extremely high velocity, such as near bucket tips. Erosion is always accelerated by corrosive electrolyte.

A paper by **T. W. Bigger, J. F. Quinlan** and **C. C. Carson,** all of General Electric Company, reported results of tests comparing the resistance of various actual and possible steam turbine materials to corrosion-erosion with wet steam extracted from an operating turbine. Also, to determine the cause of the corrosion, chemical studies were made of the liquid phase at the temperature and pressure of the dewpoint in the turbine. From these studies it was learned that the pH of the fully condensed steam from the same point and the sulfur compounds from boiler sulfite were a principal cause of the lowered pH with its attendant corrosion.

The authors reported that a statistical study of the relationship of various boiler-water treatments to corrosion in a number of power stations is being carried out, and further chemical studies are planned. The results will be reported later.

Discussion

It was pointed out that where sodium sulfite is employed as an oxygen scavenger in the boiler, its decomposition will result in corrosion attack in the turbine. Carbon dioxide in the steam will also contribute to such corrosion.

Professor F. G. Straub discussed the desirability of a simple method of sampling for chemicals in which definite locations would be prescribed for taking the sample. In this connection, he mentioned a study that has been set up involving fifteen turbines operating in various parts of the United States.

Economic and Design Considerations for Selection of Large Power Plant Stacks

By H. L. VON HOHENLEITEN and R. H. KENT

Consolidated Gas Electric Light and Power Co. of Baltimore

In this paper presented at the Annual Convention of the Air Pollution Control Association at Baltimore, May 25–28, 1953, the authors discuss current problems entering into stack design, including comparative initial and maintenance costs of steel, concrete and brick stacks, stack heights, outlet gas velocities and dust concentrations. Wind-tunnel tests are cited.

IN the not too distant past, the engineer's job in selecting a stack was a comparatively simple one. All he had to do was to satisfy himself that the stack was providing sufficient draft for the particular boiler or boilers it was to serve, and that it was adequate from a structural standpoint. Now the sole function of a power plant stack is dispersion of the products of combustion in the most effective and desirable manner. This apparent simplification of purpose has resulted in creating a complex problem which requires the careful collection and analysis of a large mass of related data.

Several papers dealing with this subject have already been presented (1 and 2) and it is not the purpose of this paper to present needless repetition. Consequently, some of the many problems that face the designer will be assumed as solved and this discussion will deal with a hypothetical plant consisting of a number of 100,000-kw units. This specific size is used here as a convenient base unit for analysis and expression of quantities. Costs will be expressed in terms of relative units instead of dollars.

In this analysis it will be assumed that each boiler is to be provided with its own stack; that the arrangement of the induced-draft system with its dust collectors will be along the "ranch type" design and that the stack will be supported at the ground level. It will also be assumed that the soil conditions are such that the stack will be founded on piles that will not be subjected to up-lift under any load conditions.

The range of fuels, the amount of excess air, allowance for air leakage, estimates of gas temperature, and the maximum cubic feet per minute of flue gas per boiler having been determined, a start can be made with an estimate of the approximate stack dimensions.

Approximate Stack Dimensions

Until recently, the stack diameter was chosen to give a minimum practical friction loss. In many cases, this resulted in a stack velocity of the order of 50 fps. With the necessity for higher and higher stacks in order to achieve proper dispersion of the combustion products, the designer will find that friction loss is no longer the proper criterion for selection of the optimum diameter. In order to get reasonable relations between stack diameter and height for structural considerations, he will have to choose a much larger diameter which, in turn, will materially reduce the flue gas velocity through the stack barrel. In order to provide the necessary emission velocity, nozzles may be introduced at the top of the stack.

The relation between stack diameter and height is especially important in the case of a self-supporting steel stack. In the past, this type of stack has been designed largely by means of arbitrary values which substituted a larger factor of safety for accurate knowledge. Recent developments have shown that resistance to ovaling, natural frequency of vibration, and buckling strength should be investigated and that considerable work remains to be done on these three subjects. An approximate estimate of required height can be made by the use of the earlier Bosanquet and Pearson formula (3). For purposes of illustration, it will be assumed that an inside diameter of 20 ft and a height in the neighborhood of 300 ft have been established as tentative stack dimensions.

Type of Stack Construction

Three types of stack construction will be considered. First, self-supporting steel stacks with gunite lining; second, reinforced concrete stacks with independent brick lining; third, brick stacks with independent brick lining. Costs for the first type will usually have to be worked out by the designer, while those for concrete and brick stacks will have to be obtained from stack construction companies. In order to get a sufficient number of points for plotting, it will be advisable to design stacks for the preliminary height as well as 50 or more feet higher and possibly 50 ft lower. Foundations for all of these cases will have to be worked out and the results then plotted in the form of three curves as has been shown on Fig. 1.

From this graph, it appears that self-supporting steel stacks and their foundations can be constructed economically up to a certain height, approximately 275 ft,

but above that height, reinforced concrete stacks become more economical. The cost of brick stacks is out of range for any height.

However, before a true economic analysis can be made, not only the initial cost, but also possible maintenance cost, must be taken into account. This is a point upon which opinions can vary widely. Maintenance costs on gunite-lined steel stacks have been established, and many utilities have concluded that the maintenance of gunite is negligible

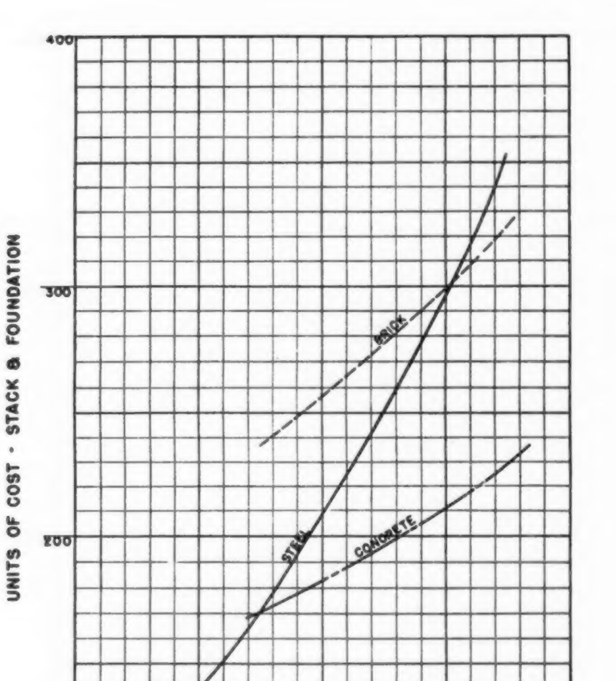


Fig. 1—Comparison of cost of steel, concrete and brick stacks for various heights

while maintenance of the steel consists largely of the cost of exterior painting. There seems to be considerable controversy as to the amount of maintenance on concrete stacks. Some users have found their maintenance to be negligible while others have had considerable expense. Local climatic conditions, stack gas temperature, and materials of construction affect the required amount of maintenance work. Brick stacks are known to stand up well for the first 10 to 15 yr of service, but after that require extensive and costly repairs.

Another point is the possible necessity for future extension of the stacks in order to keep up with ever-increasing demands from air pollution authorities and the public or the possibility of a change in character of the territory surrounding the plant. While any provision for future extension is costly, it is easily accomplished on a self-supporting steel stack and the time required for such work is usually confined to five or six weeks. The future extension of a concrete stack, although possible, is not particularly desirable and the outage time required changes from weeks to months. The same considerations apply to brick stacks. Outage time for maintenance follows a similar pattern. The capitalized value of annual maintenance averaged over a 30-yr period has in one instance shown that it might run approximately 3 per cent of the total cost of stack and foundation for a steel stack, from 5 to 16 per cent for a concrete stack, and approximately 8 per cent for a brick stack.

If the preliminary design height happens to fall below the critical point where the steel stack and concrete stack curves intersect, the answer is evident, but if the design height should happen to fall a short distance to the right of this intersection point, a decision must be made as to whether the saving in initial cost effected by the use of a concrete stack is worth the risk which higher maintenance costs and prolonged outage time may bring.

Stack Outlet Velocity

In past years, it has been recognized by a large number of designers that a high gas outlet velocity has some distinct advantages, especially in cases where there are limitations to the height of stacks due to their proximity to airports. These higher exit velocities, which in effect act like an extension to the stack, remained under 100 fps until a few years ago; but recently some plant designers have chosen higher velocities.

From wind tunnel tests conducted by Dr. E. F. Wolf and the writer in 1941 (7), and from subsequent observa-

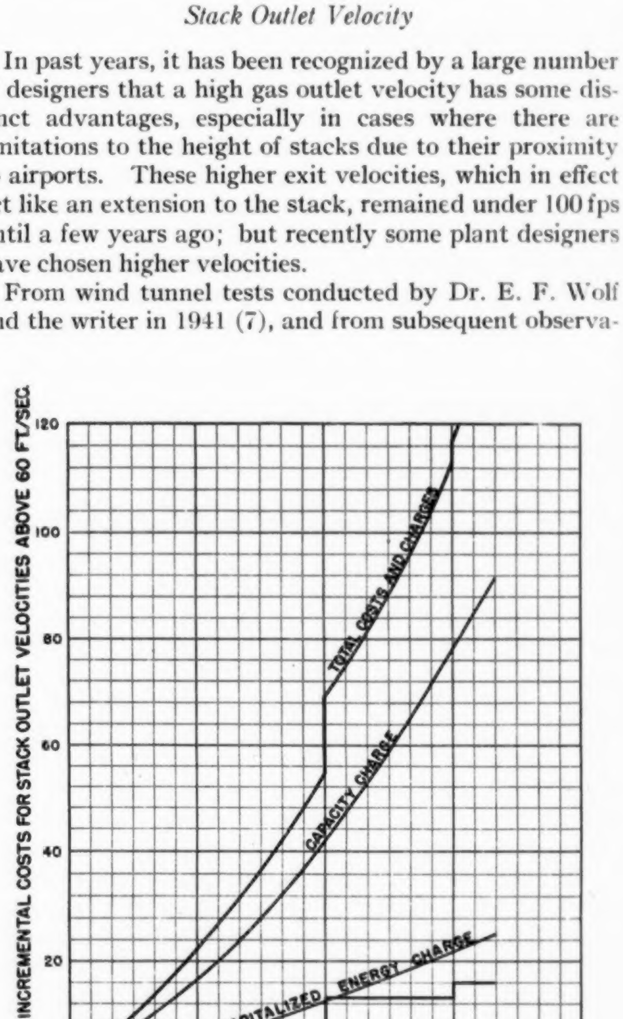


Fig. 2—Comparison of cost for different outlet velocities with top of stack at 300-ft elevation

tions of the prototype installation, it was learned that an outlet velocity of 60 fps prevented the flue gases from being caught in the stack vortices with wind velocities up to approximately 35 mph. Sixty fps was the outlet velocity used in earlier installations. However, velocities of 90 fps give protection for wind velocities reasonably in excess of 35 mph.

The choice of outlet velocity has to be influenced to a large degree by economic considerations. On the basis

of accepting 60 fps as an absolute minimum, incremental costs for various outlet velocities and two or three different stack heights should be computed. Taking capitalized energy cost, capacity charge, cost of fan, and cost of motor into consideration, we arrive at curves similar to those shown in Fig. 2. One can readily see that the higher outlet velocities represent a sizable investment.

Dust Collector Installation

Before making any calculations on discharge and dispersion, the engineer must decide what type and size of dust collection equipment must be considered. For the purpose of this illustration, it is assumed that overall efficiencies in excess of 95 per cent are specified for a plant of this size. Some manufacturers of electrostatic precipitators offer large electrical units exclusively, but the engineer will do well to prepare preliminary layouts for a high-efficiency installation to determine whether the necessary space is available for the required low gas velocity and for proper distribution of gases to and from such large collectors. If he makes a conservative choice of gas velocity through the collectors, say 65 fps, in order to insure sustained high efficiency performance, he may find that the width required for such an installation may easily exceed the width of the boiler room. Such a layout would likely involve trouble with the second and subsequent units. Hence, where width is the limiting factor, a solution may be found through use of a series-combination unit with a mechanical dust collector in the leading position and an electrostatic precipitator in the trailing position. While the cost of such an installation is quite high, in the neighborhood of half a million dollars for larger units, it has the advantage that high overall efficiencies can be maintained without difficulty, and that in case of an interruption to the electrical precipitator, the mechanical unit is still capable of collecting a large percentage of the flue dust.

For the example chosen a mechanical dust collector of 83 per cent efficiency will be assumed, followed by an electrostatic precipitator of 85 per cent efficiency. This would mean over 97 per cent overall efficiency for the series collectors.

Maximum Concentrations at Ground Level

It is now possible to compute maximum dust concentrations at ground level by means of a modification to the latest Sutton formula which even permits taking gas outlet and wind velocities into account. However, while boiler load and outlet velocity may be kept constant by the power plant operator, he has no control over wind velocity, and it is well known that the wind remains constant neither in intensity nor direction. This results in a much better actual dispersion than the theoretical formulas would indicate.

Under the climatic conditions which generally prevail in this area (Baltimore), a suspended dust concentration of 5.5 mg per 1000 cu ft does not generally produce a visible haze; therefore, this value may be used here as the maximum suspended dust concentration at ground level at any point in line with the gas trail emanating from the stack.

The engineer must gather data on existing plants in order to be able to apply a correction factor to the theoretical values. Too little work has as yet been done on this phase to permit definite conclusions. From the few observations made in one location, an average factor of 1 to 4 seems to be indicated, and for purposes of this study, this factor will be used.

The above-mentioned modified Sutton formula also permits the calculation of SO_2 concentrations at ground level.

Concentrations of 2 ppm are the lowest which can be detected by most people with an acute sense of smell, and

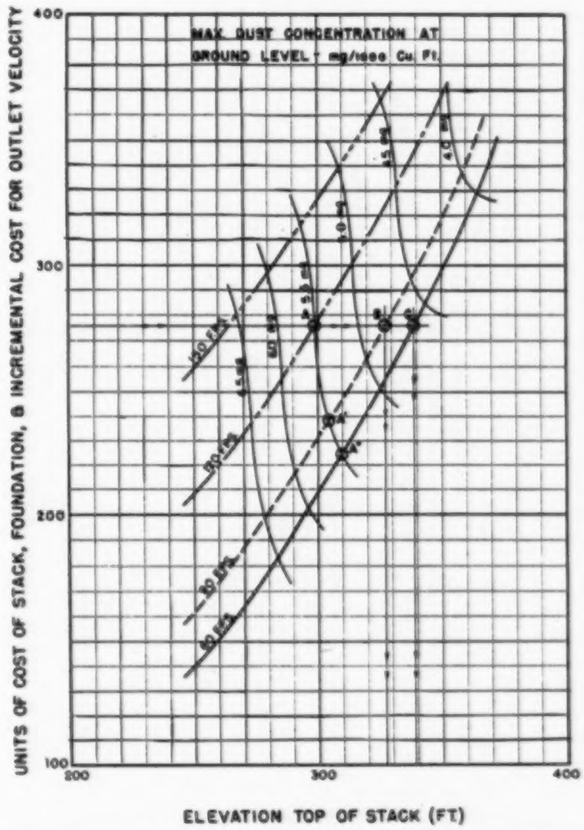


Fig. 3—Comparison of various heights, outlet velocities and dust concentrations with steel stacks

British papers have suggested a maximum acceptable limit at ground level of 1.9 ppm.

Again, for illustration, we shall choose an arbitrary relative value, say unity. The absolute value will depend upon the sulfur content of the particular fuel that is used.

Stack Height Versus Outlet Velocity

On Fig. 3, cost curves for steel stacks, including foundations, have been plotted for four outlet velocities. The solid line represents the base cost of a gunite-lined steel stack, and since 60 fps has been assumed as the minimum outlet velocity, no extra charges have been added. The three curves above this, for 90, 120 and 150 fps, represent the sum of the stack costs plus the incremental costs for the raised outlet velocity.

There has also been added a family of intersecting curves to this graph which represent values for maximum duct concentration at ground level, computed by the modified Sutton formula.

It will be noted that the 5.5 mg per 1000 cu ft dust concentration curve intersects the 120-fps stack curve at point A, corresponding approximately to an elevation of

300 ft and 276 units of cost. If this dust concentration curve be followed on down to point A′, it will be seen that this intersection with the 90-fps stack line indicates a stack elevation of 305 ft at a cost of 239 units. Following this curve farther on down to point A″, it will be found that a stack built to elevation 310 ft with 60 fps outlet velocity would give the same maximum dust concentration for 225 units of cost, representing a saving of 14 units over point A′ and 51 units over point A.

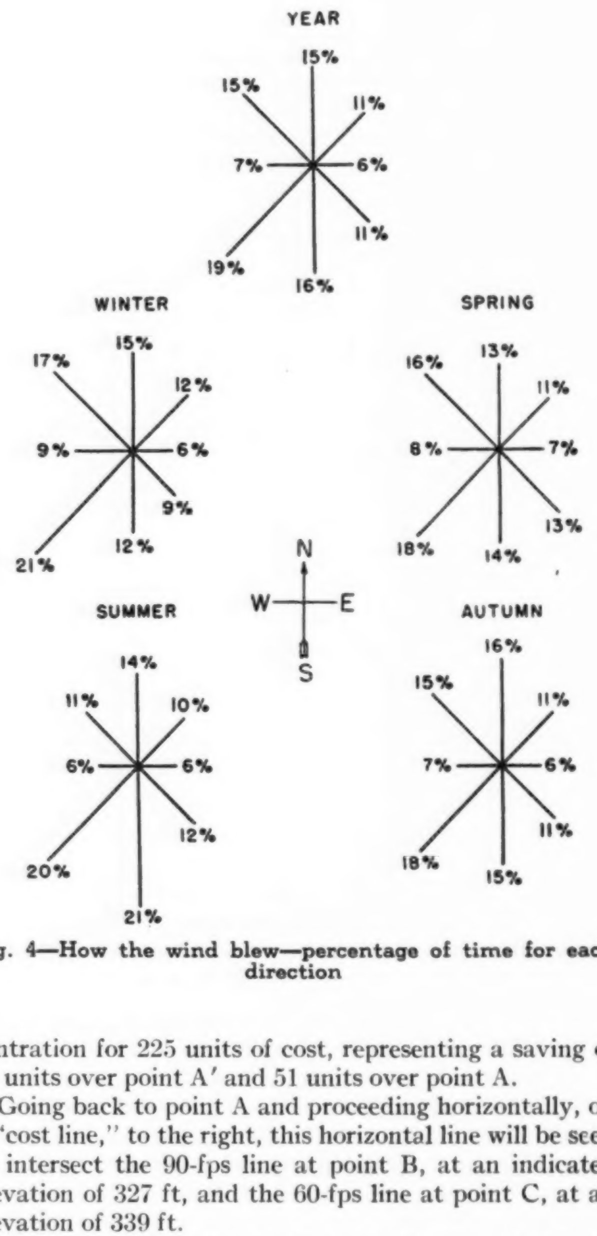


Fig. 4—How the wind blew—percentage of time for each direction

Going back to point A and proceeding horizontally, on a "cost line," to the right, this horizontal line will be seen to intersect the 90-fps line at point B, at an indicated elevation of 327 ft, and the 60-fps line at point C, at an elevation of 339 ft.

Since the full benefit of outlet velocity can only be obtained when the unit is working at full load, whereas additional height of stack will be beneficial at any load, it can be seen that, for a given amount of money, it is more economical to invest it in additional stack height rather than to spend it for additional outlet velocity.

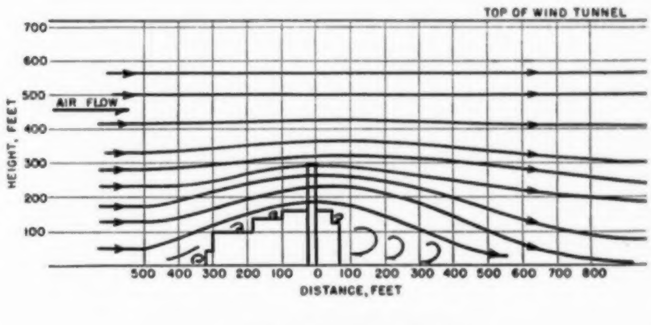
There is, however, a further benefit which can be derived from additional stack height. Traveling along a horizontal "cost line" from left to right, dust concentration curves of lower and lower values are being intersected. From the graph, one can read a dust concentration of 4.8 mg at point B and 4.6 mg at point C, representing an improvement of $12^1/_2$ per cent and 16 per cent, respectively.

Geographical Location

The next important consideration is the geographical location of the plant. By superimposing the proposed location of the stack (or stacks) on a map of the surrounding territory and by drawing circles of maximum concentration of suspended dust in the air at ground level, it can be seen whether these circles strike any built-up areas. Serious consideration must also be given to the possible future development of the area. Is it going to be largely industrial or is there a chance of further residential expansion? In connection with this, the prevailing winds must be studied (Fig. 4) (9). It is not sufficient to rely on the fact that prevailing winds might, for example, be in a northeast direction for one season of the year and, possibly, southwest direction for another season, but it is necessary to study cumulative wind roses for the four seasons of the year. If these wind roses should indicate that the wind blows toward a development, say, 40 per cent of the time during the outdoor seasons, this, too, will be a definite indication that special attention must be paid to the flue gas dispersion problem. Prevailing wind velocities in critical directions and frequency of atmospheric inversions must also be taken into consideration. If this check of the geographical location reveals that the original assumptions still hold good, then it is time to proceed with the next step in the analysis.

Size of Ultimate Plant

The picture is not complete unless one takes the size of the ultimate plant into consideration. For example, starting with a six-generator plant of 600,000 kw ultimate capacity, investigation should be made as to what would happen if additional generators are added beyond the original layout.



BUILDING TURBULENCE PATTERN

Fig. 5—Wind-tunnel tests

Based on the previously mentioned computations and the values shown in Fig. 3, the results can be presented in tabular form. This will establish how many generators can safely be installed for a given stack height and at the same time determine what type of duct collector installation will provide the necessary protection.

TABLE 1

Stack height for six generators = 600,000 kw. Assumed maximum permissible concentrations:

SO_2 = 1 Unit
Dust = 5.5 mg/1000 cu ft

	Top of Stack at El. 300 ft					
No. of Generators	1	2	3	4	5	6
SO_2, units	0.16	0.32	0.48	0.64	0.80	0.96
Dust: mg per 1000 cu ft						
Mech. collectors only	2.20	4.40	6.60	...	...	...
Series collectors	...	...	1.32	1.76	2.20	2.64

From Table 1, it can be seen that mechanical dust collectors only would be adequate for the first two generators, but it would be necessary to install series collectors for each generator by the time the third one goes into operation to meet the assumed dust limitations. The stack height (El. 300 ft) is satisfactory for six generators.

Now assume further that the plant will be expanded to eight generators, with a total capacity of 800,000 kw.

TABLE 2

Stack height for eight generators = 800,000 kw. Assumed maximum permissible concentrations:

SO_2 = 1 unit
Dust = 5.5 mg. per 1000 cu ft

	Top of Stack at El. 300 ft						At El. 345 ft	
No. of Generators	1	2	3	4	5	6	7	8
SO_2, units	0.16	0.32	0.48	0.64	0.80	0.96	0.88	1.00
Dust: mg per 1000 cu ft								
Mech. collectors only	2.20	4.40	6.60	...	...	...	...	...
Series collectors	...	...	1.32	1.76	2.20	2.64	2.44	2.78

Table 2 indicates that the addition of the seventh and eighth generator, for an ultimate capacity of 800,000 kw, would require an extension of all stacks to El. 345 ft. With a series-collector installation, the dust emission poses no problem even for the eight-unit plant.

Selection of Stack Height and Dust Collectors

The engineer can now choose between several combinations:

1. He may decide that the ultimate capacity of the plant will never exceed 600,000 kw. In this case, stacks to El. 300 ft are satisfactory.
2. An increase in size of the ultimate plant to 800,000 kw must be expected and he can then
   a. build all stacks to El. 345 ft, or
   b. design the stacks for El. 345 ft but build them to El. 300 ft only for the first six generators. All stacks must then be raised with the seventh unit. In that way, he can effect some saving in capitalized costs.
3. He must provide the necessary space for series collectors and can either
   a. install the series collectors from the start, or
   b. defer the installation of electrostatic precipitators until the third generator goes into service.

Which of these combinations he chooses will depend entirely on his particular problem and how it is affected by all the aforementioned points.

Wind-Tunnel Tests

There remains, however, one further step before the engineer can feel reasonably sure that the foregoing analysis has really given him the correct answer.

As mentioned before, the theoretical formulas which have been used to determine concentrations at ground level are all based on uniform air movement and do not allow for disturbances created by the power plant building, and possibly adjacent structures. These structures will tend to deflect the air currents and create turbulent zones in the wake of the buildings. Unless the stack gases are discharged well above the turbulent zone, the concentrations at ground may occur at a much shorter distance and at greater intensity than those indicated by the formulas.

The engineer will do well to resort to simple wind tunnel tests (7) (8) to study the turbulence pattern of the power plant structures (see Fig. 5) to assure himself that the top of the stack is high enough to keep the gases out of any possible downdraft. Only after he has confirmed his stack height by such tests, can he proceed with reasonable assurance that his theoretical calculations will provide a fairly close answer.

Conclusions

The design of a stack for a large power plant is no longer a simple structural problem, but one which is largely governed by attempts at proper gas dispersion and economic considerations. Type of stack construction, stack height, stack outlet velocity, maximum concentrations at ground level, type of dust collector installation, geographic location of the plant, and size of ultimate plant, all must be weighed before a definite recommendation can be made. As a final step, the engineer should check his findings by wind-tunnel tests in order to avoid grave errors.

It is fully recognized that the foregoing discussion gives a general analysis of the subject only, and it is intended rather as an outline which must be varied to meet each individual case. Much experimentation and carefully collected data are needed in each specific case before the engineer will be able to undertake the design of modern stacks with an adequate sense of assurance.

Acknowledgments

The authors wish to express their appreciation to Messrs. E. F. Wolf, W. N. McDaniel, A. H. Plantholt and Miss Phyllis Crichton, of the Electric Test Department, and Messrs. G. S. Harris, W. MacWilliams, Jr., M. Tomko and L. D. Homan, of the Electric Engineers Department, of the Consolidated Gas Electric Light & Power Company of Baltimore, for their valuable assistance and suggestions.

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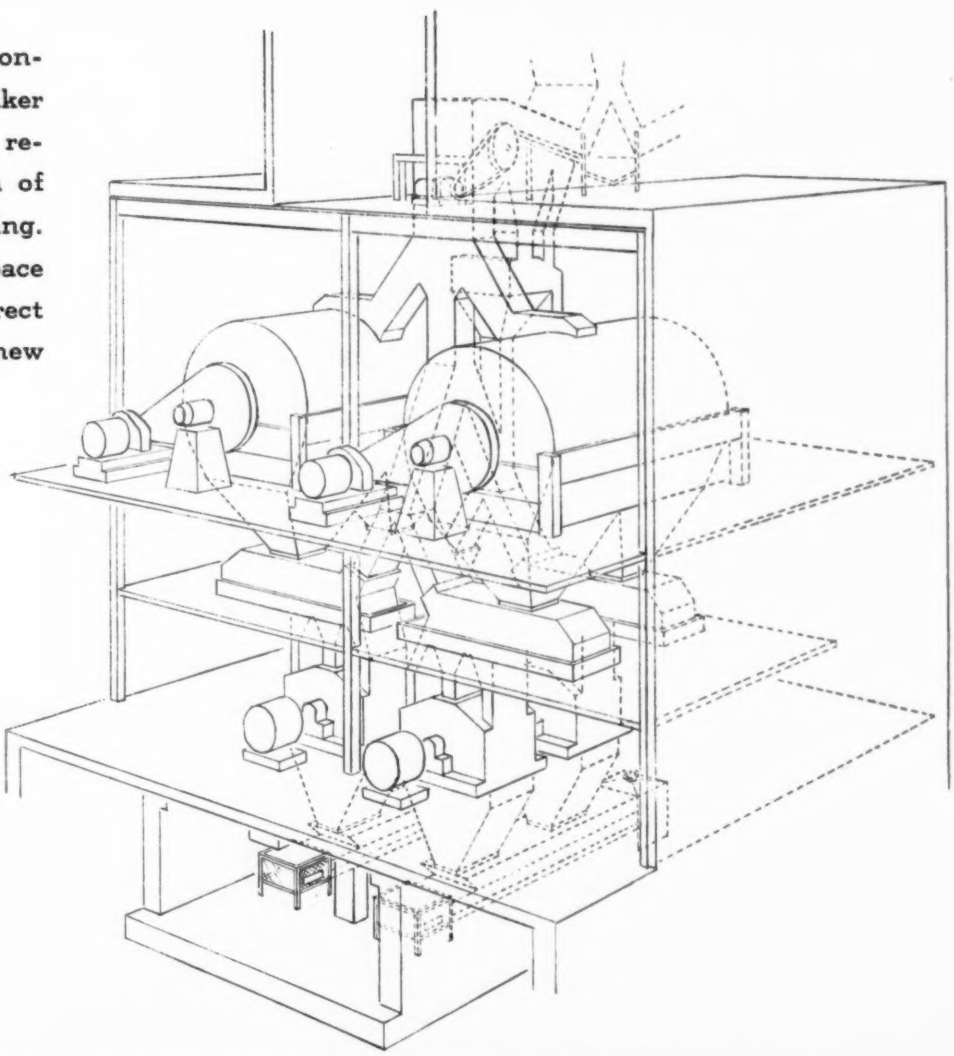
New Design of Pennsylvania Bradford Breaker Is Space Saver

This article compares conventional Bradford breaker design with improvements resulting from the adoption of central peripheral feeding. Perspective views show space savings achieved as a direct result of adoption of the new design.



Cutaway view showing building-volume saving with improved design of Bradford breaker at a midwestern central station now under construction

BACK in 1873 Hezekiah Bradford of Reading, Pennsylvania, was granted a patent for an improvement in coal breakers. So sound was his conception that today the type of breaker bearing his name is still being constructed to essentially the same basic design. The original breaker had an open end and was roller mounted. A large cylinder perforated with numerous holes was revolved on the rollers. The coal was lifted by shelves inside the cylinder and was allowed to fall to the bottom, where it was shattered by gravity impact, the small pieces sifting through the perforations. By means of deflectors refuse material was caused to move forward into a separate discharge chute.

Today the amount of economically available space in central stations is quite limited, and the trend is toward marked reduction in building volume and to outdoor construction. Quite naturally coal-handling systems have been affected by this tendency, and manufacturers of coal-handling equipment have taken steps to meet conditions of greatly increased output in less space than heretofore was required. An outstanding example is the successful redesign of the Bradford breaker by engineers of the Pennsylvania Crusher Company.

Conventionally, Bradford breakers have been fed from one end of a large, slowly rotating cylinder. Where desired a hammer rotor has been located at the end opposite from the feed. The new design permits peripheral feeding at the center of the breaker and makes possible the installation of hammer rotors at both ends of the breaker.

The feed enters at right angles to the rotating axis of the new Pennsylvania breaker, whereas in the conventional Bradford breaker feed enters at one end.

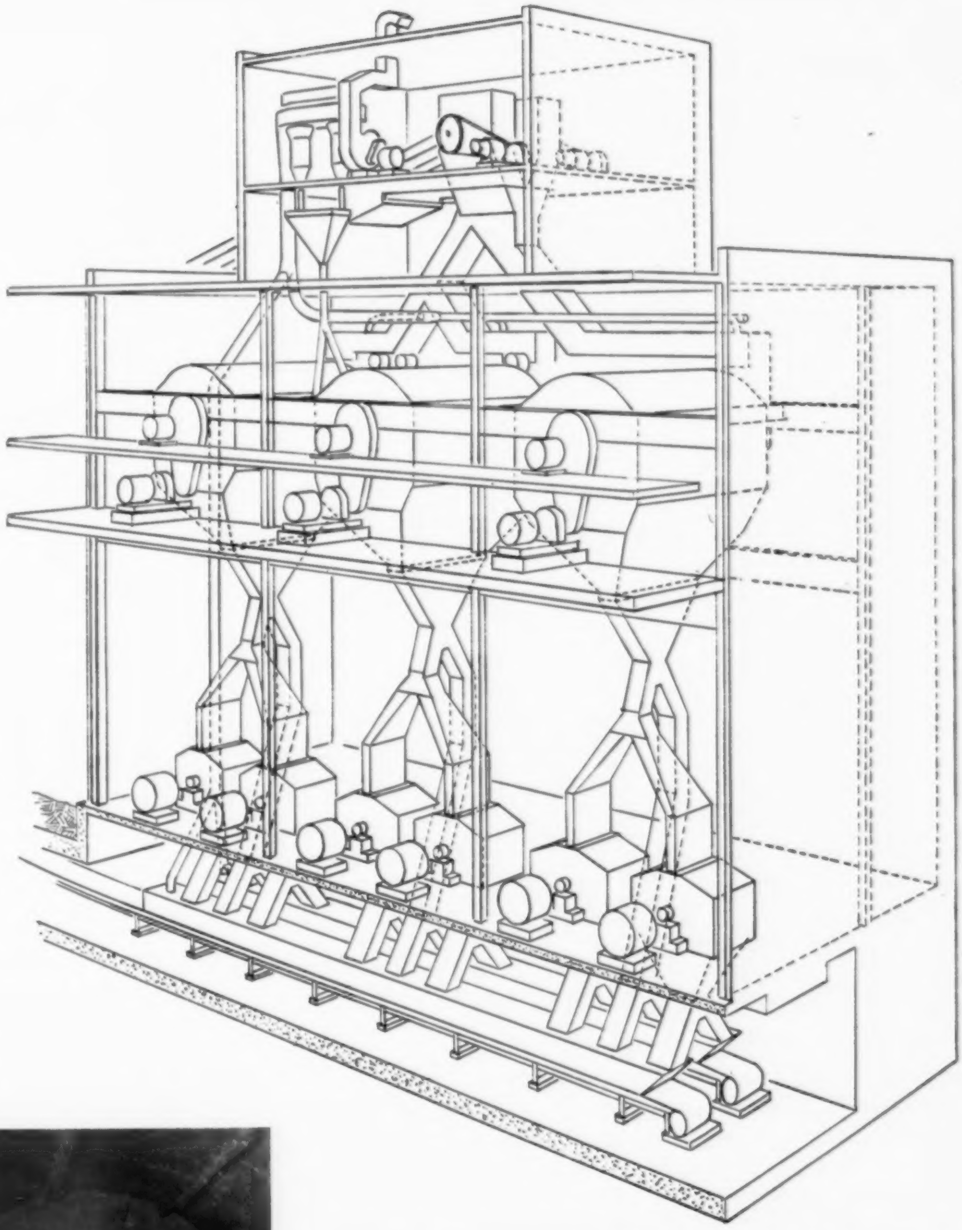
The point of entry is approximately forty-five degrees above the center line on the periphery. This permits the coal to be divided by gravity on the upper sloping-feed chute sections. These chute sections are fastened to the breaker beams completely surrounding the entire circumference of the huge cylinder, and thus continuous openings are presented to the feed.

Center feeding enables incoming flow of coal to be split, half being directed toward either end of the breaker. This splitting of the entering coal stream not only results in a substantial increase in the breaker capacity but also permits a new arrangement of the hoppers beneath the breaker so as to appreciably reduce the height of structure required.

There are other advantages accruing to center feeding. One is that the problem of build-up of coal when the breaker is end fed is greatly decreased. A thick bed is not so likely to be formed when the same quantity of

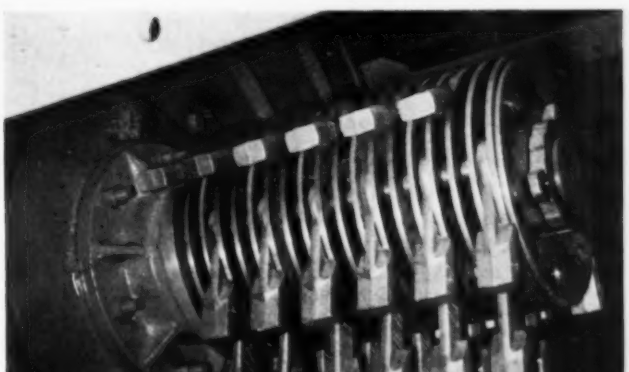
coal is fed two ways from the center. In addition, there is a substantial scattering effect resulting from spilling the coal down the center chute. This scattering effect increases the effective area of initial screening. Also, because of the thinner coal bed with this method of feeding, the impact effect of coal dropping after it rises in the breaker will be greater. Furthermore, more agitation of the coal is to be expected with peripheral feed than with end feed.

As an example of the effectiveness of the new Bradford breaker design in conserving space in central stations, the accompanying two perspective views are presented. These show installation of substantially equivalent capacity at two midwestern central stations. It can be seen that two of the redesigned breakers do the work of three of the conventional type. In addition the height of the structure has been decreased by about one-third, and the building volume is just one-half that required for installation of equivalent capacity in conventional Bradford breakers.



Cutaway view showing building volume required at a midwestern central station for Bradford breaker of conventional design

Interior of Bradford breaker showing hammer rotor, lifting shelves and deflectors



Close-up of hammer rotor

Mixed-Bed Demineralizing

By MARTIN E. GILWOOD

Director of Research, The Permutit Co.

In this paper, presented at the Chicago Meeting of the American Institute of Chemical Engineers, the author describes a method of obtaining very high quality water for high-pressure boiler-feed makeup, presents results of comparative tests with two-step demineralization, and gives comparative cost figures.

DEMINERALIZATION by ion-exchange is now available to produce the equivalent of distilled water. It accomplishes the same result as evaporation and differs only in the method of accomplishment. The evaporator removes the water as vapor from the mineral solids which concentrate in the evaporator, whereas demineralization removes the solids through the medium of ion-exchange resins.

Throughout the United States, designing engineers of power plants have taken a leading part in promoting the use of higher steam pressures. Many plants are operating at 1400 psi, some at 1800 to 2400 psi. These higher pressures have demanded the use of makeup water of minimum, and preferably no, mineral solids. Formerly, such a quality of makeup water could be obtained only by evaporation. Now, with the advent of high capacity cation-exchangers and highly basic anion-exchangers, complete removal of solids from these waters is possible.

Soluble silica is a common constituent of practically all natural water supplies. The amount present may range from as little as 1 to over 100 ppm This silica is an extremely undesirable impurity in boiler feedwaters and is especially harmful in high-pressure power plants. It not only forms scale in the boilers, but also, as it is carried over in the steam, it forms deposits in the superheater tubes and on the turbine blades. These deposits are hard, adherent and difficult to remove.

Mixed-Bed Demineralization

The dissolved mineral matter in water is not present as undissociated salts, but is instead present as equal quantities of positively charged cations and negatively charged anions. Those most commonly encountered in various water supplies are shown in Table 1.

If the water contains very appreciable amounts of sodium sulfate or sodium chloride, and the end use tolerances are very small, mixed bed demineralization treatment of waters is recommended.

In the mixed bed, the cation- and anion-exchangers are intimately mixed before the demineralization run. The effect therefore is similar to an extremely large number of alternating cation and anion units. Under such conditions, the removal of electrolytes is so complete that the effluent may have a specific resistance of some 15 to 18 million ohms which corresponds to 0.01 ppm of ionized salts. Silica is only slightly ionized and therefore has very little effect on electrical resistance.

TABLE I

Cations		Anions	
Calcium	(Ca^{++})	Bicarbonate	(HCO_3^-)
Magnesium	(Mg^{++})	Carbonate	(CO_3^{--})
Sodium	(Na^+)	Sulfate	(SO_4^{--})
Potassium	(K^+)	Chloride	(CL^-)
Iron	(Fe^{++})	Nitrate	(NO_3^-)
Manganese	(Ma^{++})	Silicate	($HSiO_3^-$)
Aluminum	(Al^{+++})	Silicate	(SiO_2^{--})

Experience and research in operating boilers at pressures above 1000 psig has indicated the importance of maintaining the silica concentration in the boiler saline at levels below 5 ppm (1).[1] Higher silica levels result in solution of silica in the steam and subsequent silica deposits on the turbine blades in the lower pressure stages of the turbines. At pressures of 1800 to 2000 psig and higher, the maximum silica permitted in the saline may frequently be less than 1 ppm of SiO_2. Since the makeup water is concentrated many times in the boiler, engineers frequently specify that the treated makeup water must contain no more than 0.1 ppm of SiO_2.

The commercial development of strongly basic anion-exchangers about six years ago made it possible by ion-exchange to produce water low in electrolyte and low in dissolved silica (2). These anion-exchangers were first employed in the two-step demineralization process employing intermediate degasification between cation-exchanger and the highly basic anion-exchanger. A number of units employing this two-step process have been installed in large power plants during the past few years.

The mixed-bed demineralizing process is of special interest because it provides, in effect, a series treatment by a great number of individual demineralizing steps with the result that electrolyte impurities are reduced to the vanishing point. The purified water thus contains such a small amount of inorganic impurities that it cannot be determined accurately by conventional water analysis methods but can be checked only by conductivity measurements. Since highly basic anion-exchan-

[1] See Bibliography.

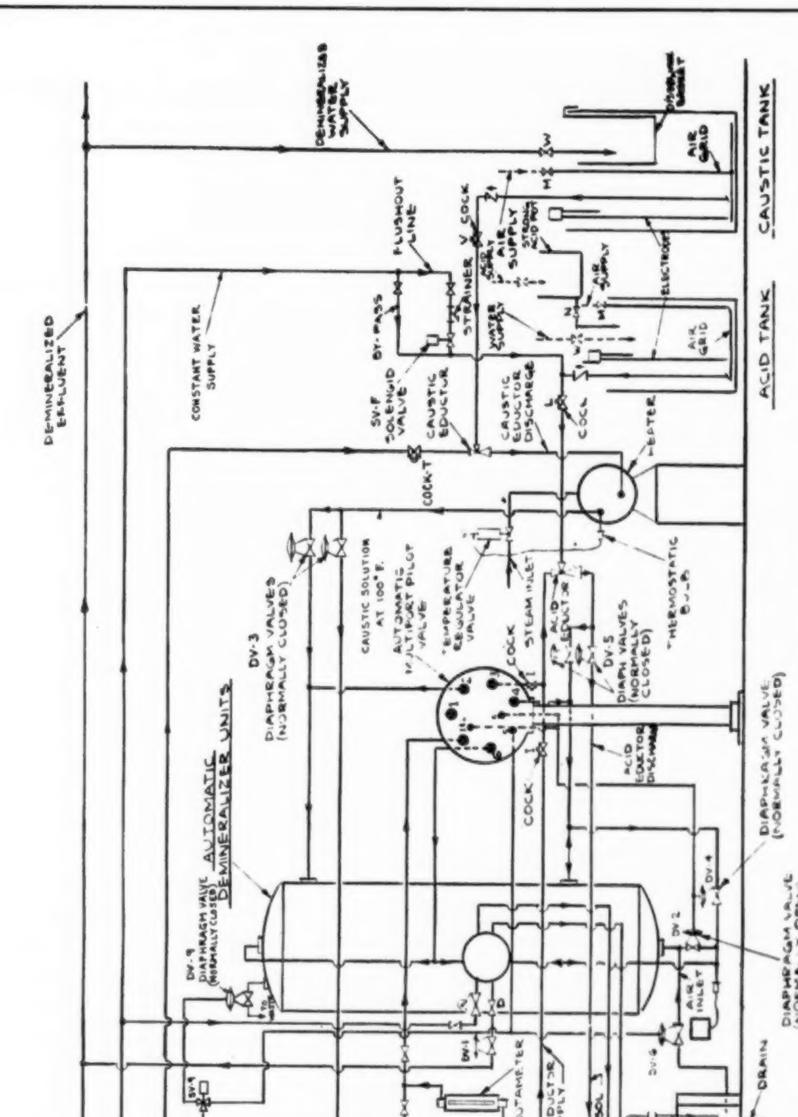


Fig. 1—Flow diagram of demineralizing installation in large central station

gers can be employed in the mixed-bed demineralizer, the silica content of a water can also be reduced to extremely low levels. In the past few years, commercial development of mixed-bed demineralization employing a mixture of cation- and anion-exchangers in a single bed has been furthered.(3)

The power plant engineer does not attach much importance to the ability of a demineralizer to produce water of extremely low conductivity or high resistivity. In fact, he most often adds some chemicals, such as phosphates, sulfites and hydroxide to protect the boiler against corrosion and deposits. Modern demineralizing is important in this field because silica can be removed from water to levels of 0.1 ppm of dissolved SiO_2 or lower.

A fully automatic mixed-bed demineralizer was recently installed at a large steam electric station in central New York State. Fig. 1 is a flow diagram of the demineralizing installation. Two mixed-bed demineralizer units, 42 in. diameter by 7 ft high are provided, each capable of treating 48 gpm of filtered raw water. This plant provides all the make-up water for a 1450-psig boiler having about 0.5 per cent makeup. Motor-operated disk-type multiport valves and diaphragm-operated valves are employed. The double unit installation makes it possible to supply demineralized water at all times, even when one unit is out of service for maintenance.

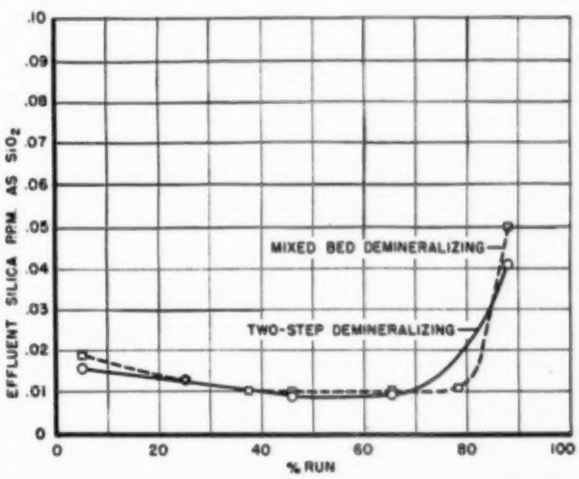


Fig. 2—Results of test runs with mixed-bed and two-step demineralizers

Considerable test work has been carried on to determine how effectively silica can be reduced by mixed-bed demineralization. This has indicated that with careful operation and warm regeneration, it is possible to reduce the silica content of the water to as low as 0.01 ppm dissolved silica. In these low amounts silica must be measured by the modified Bunting colorimetric technique described by Robinson, Pirsh and Grimm (Armour Institute) (4) employing a spectrophotometer operating at 820 mμ. Even then, there is considerable doubt as to the accuracy of the silica measurements in this range.

Parallel tests have been made treating the same water by the same anion exchange resin (Permutit S-1) in a mixed-bed demineralizer and a two-step demineralizer. In these tests, some slight variation in effluent silica was found to occur on successive runs. Fig. 2 illustrates one of the best test runs obtained in a series of runs employing each process.

In this series of runs, the effluent silica varied for 0.005 to 0.02 ppm by each method. The resistivity of the mixed-bed demineralized water varied between 6 and 13 megohms-cm whereas the resistivity of the two-step demineralized water varied from 0.25 to 0.5 megohms-cm during the runs.

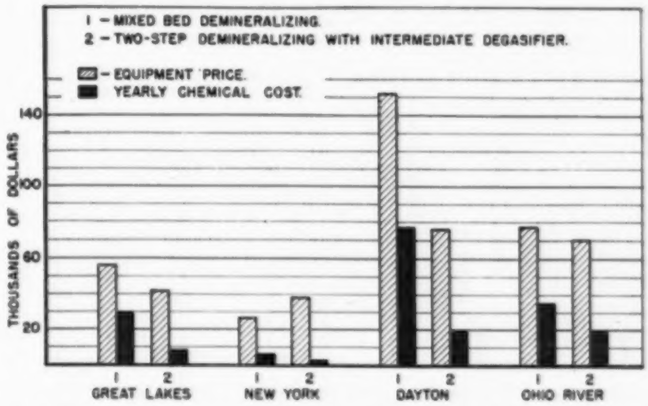


Fig. 3—Cost comparison between mixed-bed and two-step demineralization with degasifier for 300 gpm

Influent Water:

MO alkalinity	= 118 ppm as $CaCO_3$
CO_2	= 2 ppm as CO_2
SiO_2	= 16 ppm as SiO_2
Chloride + sulfate	= 14 ppm as $CaCO_3$

Anion regenerant: 6 lb NaOH per cu ft applied as 5 per cent solution at 110 F.

These test results indicate that it is possible to obtain demineralized water containing as low as 0.01 ppm SiO_2 by mixed-bed demineralizing and also by two-step demineralizing in the best runs. It, undoubtedly, requires extremely careful operating control to continuously obtain results approaching these, in large-scale plant operations.

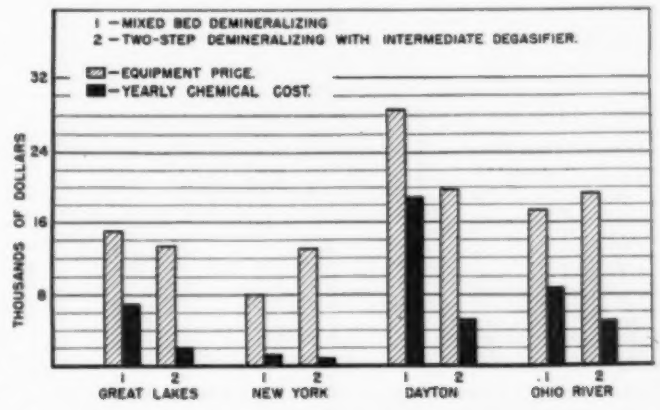


Fig. 4—Cost comparison between mixed-bed and two-step demineralization with degasifier for 50 gpm

It is not so difficult to obtain such extremely low silica residuals by either mixed-bed or two-step demineralization when treating waters containing a comparatively

low silica total anions ratio, i.e., less than 1/10–1/5. Where the silica total anion ratio is much higher it becomes more difficult to maintain the residual silica at the 0.01 ppm SiO_2 levels and more vigorous regeneration conditions must be maintained.

In mixed-bed demineralizing, the bicarbonates are not usually removed from the water prior to contact with the anion-exchanger. In two-step demineralizing, however, this is usually the case. The silica total anion ratio at the anion-exchanger, when treating the same water by the two methods, will be much lower with mixed-bed demineralization. Thus, low silica residuals should be obtained more readily in mixed-bed demineralizing.

However, this advantage of mixed-bed demineralizing can be only obtained as a result of higher chemical operating cost; that is, sodium hydroxide needed for bicarbonate and CO_2 in influent water. It appears that similar ease in silica removal and in obtaining low silica levels is attained in both processes if the loading of silica on the anion-exchanger is kept low in the two-step process. This can be done by cutting off the anion-exchange runs of the two-step treatment, somewhat before the normal exhaustion point.

Figs. 3 and 4 illustrate a comparison of mixed-bed and two-step demineralizing chemical operating and installation costs on various waters, listed on Table 2.

TABLE 2—TYPICAL WATER ANALYSES

	Ppm as	Great Lakes	New York (Catskill)	Dayton Ohio	Ohio River
Total hardness	$CaCO_3$	124	20	370	126
Sodium	$CaCO_3$	16	5	20	72
MO alkalinity	$CaCO_3$	98	12	278	45
Chloride and sulfate (ThMA)	$CaCO_3$	42	13	112	153
Silica	SiO_2	4	2.4	10	16

It is evident that the equipment cost for mixed-bed demineralizing is lower than for two-step demineralizing when treating a low solids water like New York City Catskill supply. This is balanced to some extent by increased chemical operating cost. Nevertheless, it appears that a lower overall cost can be obtained by mixed-bed demineralizing when treating such a low-solids water. This study also indicates that when treating other typical water supplies, mixed-bed demineralizing is somewhat more costly than two-step demineralizing both in first cost and in chemical operating cost.

Mixed-bed demineralizing thus seems to be of advantage for producing low-silica low-electrolyte high-pressure boiler feedwater where the raw water solids are low. Further tests and large plant experience are required to determine if it is possible to continuously produce water containing less than 0.01 ppm silica by such demineralizing.

Acknowledgment

The author wishes to thank Dr. C. Calmon, Mr. J. B. Smith and Mr. G. H. Saunders for their assistance in obtaining the data reported.

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Diversified Program at AIEE Summer General Meeting

MARKING the Golden Anniversary of the founding of its Philadelphia Section, the American Institute of Electrical Engineers held its Summer General Meeting at the Chalfonte-Haddon Hall Hotel in Atlantic City on June 15–19. About 2500 engineers were present for the largest summer meeting in the Institute's history.

The Lamme Gold Medal was presented to I. F. Kinnard of the General Electric Co., West Lynn, Mass., for his outstanding contributions in design and developments in instrumentation and measurements. In accepting the medal, Mr. Kinnard, who has developed or been instrumental in developing the watt-hour meter and photographic exposure meters, stated that man's increasing ability to understand nature's secrets and to discover new scientific truths comes largely from his success in making accurate measurements. Whenever an engineer can measure and evaluate the facts of a given situation, he finds that his problems become easier.

The diversified technical program featured a conference on boiler protective devices, a series of papers on nuclear power, and reports on trends in the utility industry.

Protecting Boilers and Auxiliaries

Five papers were presented at a conference on automatic protective features for boilers and boiler auxiliaries. The first paper, "Modern High-Capacity Steam Generator Protection," was prepared by **J. C. Beres** and **J. A. Elzi** of Commonwealth Services, Inc., who discussed protection provided for turbines having ratings of 80 mw and higher and operating on the unit system with reheat. Under these conditions in current practice auxiliaries are generally electrically driven with the exception of bearing oil pumps and the like, which are direct-connected to equipment. Power supply for normal operation is obtained from a transformer connected to the terminals of each a-c generator.

The majority of the motors for auxiliary drives are constant-speed, three-phase, squirrel-cage induction motors. Hydraulic couplings are generally used if variable speed is required. In general, duplicate units are provided only in the case of boiler feed pumps, condensate and turbine lubricating-oil pumps and bearing-oil pumps. With regard to motor protection, the emphasis is on elimination of unnecessary interruptions.

Instantaneous overcurrent protection is provided for all motor circuits. Thermal devices provide an alarm on essential motors to warn the operator of overload conditions but do not trip the motor, so that the necessary steps can be taken to shut down the other motor after making other adjustments in station equipment.

For initial plant starting the station auxiliary bus for the unit to be started is energized from a transfer bus which receives its power from the starting transformer. After the unit has been brought up to speed and synchronized with the system, the station auxiliary bus for that unit is energized by the transformer connected to the generator terminals and the breaker to the transfer bus is opened.

In placing a unit on the line, motors are started manually, but a system of interlocks is provided to insure starting and stopping of the auxiliaries in the proper sequence. The induced-draft fan is the first major equipment to be started when the unit is placed in service and the last to be stopped as the unit is taken off the line. Interlocks are furnished so that one motor cannot be placed in operation before the preceding motor in the sequence has been started.

"Electrical Safety Features Used for Boiler Protection in Several Large Generating Stations in the Southeast" was the title of a paper by **A. H. Mergenthaler** and **H. B. Cox** of Southern Services, Inc. They listed four governing features in providing a satisfactory safety interlock and tripping scheme:

1. The type of fuel used and the fuel-handling equipment provided.
2. The number of draft fans per boiler.
3. The overall station service-power arrangement.
4. The type of combustion control system and lighting-off equipment used.

Requirements for control and tripping interlocks necessary to protect a pulverized-coal-fired unit supplying a turbine of less than 80-mw capacity were detailed by the authors. Additional requirements for larger units having two sets of fans were also set forth, including the starting sequence and tripping procedures. Similar consideration was given to the special conditions encountered in the control and tripping interlocks of gas- and oil-fired boilers.

In a paper entitled "Boiler Protection and Interlocking on the A.G.&E. System," **H. C. Barnes** of the American Gas & Electric Service Corp. placed emphasis upon assuring capacity availability. To do this it is necessary to give particular attention to interlocks to make sure that situations are not created which would cause accidental tripping. He advocated avoidance wherever possible of the so-called "house-cleaning" type of protection, which trips out an entire boiler or section of the station. With single boiler-turbine-generator installations this can become serious, for even though the boiler may be quickly restored, an outage of several hours may be required if it becomes necessary to remove the field from the generators.

Mr. Barnes described in detail the protective features for a 200-mw reheat unit operating at 2000 psig, 1050 F. He commented that the use of boiler control and protection is subject to the personalities of those working on a particular job, to practices carried over from the past and others established by panic due to a single failure, and to the need to cover new plant devices. To provide the desired protection with a minimum of complication requires an open mind which will carefully weigh the probabilities and the damage that might result.

Maintenance is an important consideration, for each device that is added deducts something from the maintenance of others and introduces another potential source of false operation. A simple system involving some calculated risks and reliance upon operators, especially one that is easily understood and maintained, is far superior to the complicated one trying to cover every contingency. Furthermore, by establishing in writing the need for each protective device it is possible to eliminate much complication and to determine when design changes make particular interlocks no longer necessary.

Gordon R. Hahn of the Consolidated Edison Co. of New York presented the fourth paper, which was entitled "Operating Protective Devices for Pressurized Reheat Boilers" and was based on the control system of the Astoria Electric Generating Station now under construction. With six single boiler-turbine-generator units contemplated for ultimate in-

stallation, the design is such that each unit is an entity even to its auxiliary services. Every effort is being made to isolate operating troubles to the unit involved and not to jeopardize continuity of service of the other units.

Control rooms are being provided for the units in pairs, and it is planned to operate the first pair with two supervisors, two men in the control room and two rovers in the plant on each watch. With this concentration of controls it is essential that protective devices function to limit the degree of damage which might occur through failure of some part of the equipment. Also, there has been a trend on the Consolidated Edison system to extend automatic protection of equipment for the principal purpose of relieving the operators of the responsibility of deciding when a unit is to be shut down to prevent damage.

There are three groupings of protective devices: (1) those concerned with boiler troubles, (2) those concerned with turbine troubles and (3) those concerned with generator and feeder troubles. A difficulty encountered in any of the three groups can either trip the unit or set up a sequence which may enable the trouble to be cleared.

In order to provide protective devices it was necessary to use existing measuring instruments and to equip them with means for initiating trip circuits. However, Mr. Hahn was of the opinion that these devices will become inherently more reliable because, as their need is demonstrated, they will be initially designed as protective devices. Noting that these controls and interlocks reduce the hazard of delay in removing faulty equipment, he added that equipment can be returned to service more quickly because trouble is defined and limited. Also this reduces the possibility of errors by operators during periods of stress and indecision.

The last paper, "Electrical Safety Features Used for Boiler Protection at Delaware Station," was presented by **E. E. Brown** of the Philadelphia Electric Co. Two 125-mw reheat units operating at 1875 psig, 1000 F are being installed in this plant. The generator is provided with the usual complement of differential and overload relays and with reverse power relay protection. No provision is made for automatic transfer of the auxiliary power bus, nor are there any automatic electrical tripping facilities on the turbine throttle valve.

During normal boiler operation the loss of both forced-draft fans, or one if only one is operating, will automatically stop all pulverizers and coal feeders and open the fan vanes and dampers. The boiler feed pump will be automatically tripped by either protective relays or by a loss of the pump-suction pressure for a predetermined time. There is no automatic transfer of boiler feed pumps, but an alarm is sounded and the operator must manually start another pump. A low-level alarm is sounded if the water level in the boiler is dropped for reasons other than automatic tripping of pumps.

Discussion

The five papers brought forth a wide variety of discussion on electrical and mechanical problems associated with boiler and turbine protection. There appeared to be two differing schools of thought, one favoring the installation of sufficient protective devices to prevent serious damage to components of large power units; the other, fearful of system disturbances resulting from momentary shutdown, advocated fewer protective devices with dependence more upon operator judgment. The philosophy of the first school is to shut down the equipment and ascertain the cause of trouble; that of the second is to put in protective devices only when absolutely needed. Resolving the two viewpoints poses the question of where one stops in adding protective features. Also it raises the issue of keeping a unit on the line to preserve system stability versus the possibility of damaging power-generating units representing large capital investment.

Nuclear Power Generation

In a paper entitled "The Nature of Nuclear Power" **John W. Landis** of the U. S. Atomic Energy Commission explained that, on the basis of the division of energy for a typical U-235 fission, little hope is held out for direct conversion of nuclear energy to electricity. However, several firms hold patents on direct conversion processes even though no power applications are currently envisaged. Indirect conversion using a nuclear reactor is necessary if nuclear energy is to be used on a scale of sufficient size for practical power generation.

Power reactor designs are presently in a state of flux, with many technical and economic factors requiring evaluation. Mr. Landis offered a comparison of fast and thermal reactors. The former requires a larger fuel investment than the latter and involves relatively difficult control problems. The thermal reactor may require an expensive moderator and will likely have a lower power density per unit volume than the fast reactor. The thermal reactor also permits a wider choice of coolants which simplifies heat removal and can be operated with a smaller minimum critical mass than the fast reactor. Comparisons were also presented for heterogeneous and homogeneous reactors, for regenerative and non-regenerative reactors, and for the use of ordinary and liquid-metal coolants.

The author provided figures to show that the availability of raw materials will place no limitation on the expansion of the budding nuclear power industry. Also, current "paper" studies indicate that there are several reactor designs which involve production costs within a few mills per kilowatt-hour of the national average for the cost of conventional power generation. Assuming a reasonable amount of technical progress takes place in the interim, Mr. Landis believed that appreciable blocks of competitive power with nuclear reactors would be generated by 1963, even though specific reactor designs have not as yet been crystallized.

J. M. Harrer and **J. A. DeShong, Jr.,** of the Argonne National Laboratory, in a paper entitled "Considerations for Discontinuous-Type Power Regulation of Nuclear Reactors," reported the development of an improved on-off type nuclear-reactor control system. In a nuclear reactor the power increases without limit or falls to nearly zero when the reactivity is greater or less than zero. In the design, provision is always made to control reactivity by mechanically moving neutron-absorbing rods, fuel rods or sections of the reflecting blanket.

It was decided to regulate the power of a heavy-water moderated and cooled reactor at Argonne Laboratory, known as the CP-3, with a system in which the reactor power deviation was the only control factor used to provide control-rod velocity. This system was furnished with a control dead zone so that when the reactor power was in that zone no regulating action was taken. By accurately adjusting the control-rod velocity and dead-zone size, the designers succeeded in obtaining a suitable stable performance. This system proved successful partly because it took advantage of the reactor's self-stabilizing qualities rather than working continuously to overcome small drifts in power.

The heart of this system is a light beam galvanometer which is used to measure the difference between a fixed current and the current from the neutron - flux - detection, ion - current

chamber. Photo cells at either side of the light beam center position are energized when the chamber current has deviated from the set current. When energized these cells activate relays and motor starters which operate the rod-driving motors. The authors reported on improvements in this type of system which resulted from the substitution of a simple and compact electronic amplifier for the galvanometer and the use of a motor having an appreciably shorter starting time. These changes removed undesirable delay times.

"Maintenance Problems with Reactor Auxiliaries and Instruments" was the subject of a paper by **C. B. Wagner** of the General Electric Co., who pointed out that the development of large production-type reactors has been greatly influenced by factors which favored and sometimes required the use of automatically operated machinery. Thus, the nuclear industry is furthering the trend toward so-called automatic factories wherein many operating functions are performed by machines either automatically controlled by suitable instruments, or operated remotely by a minimum staff. Because of this condition a significant portion of the overall manufacturing responsibility is necessarily transferred from operating to maintenance personnel. Reactor maintenance problems, including provisions for auxiliaries and instruments, are comparable to those of petroleum refineries or chemical processing plants, but with costly and time-consuming applications overshadowing normal considerations.

The unusual nature of reactor maintenance work arises from the fact that various radiations generated are injuries to human tissues. Efforts of shielding a reactor are not wholly effective, regardless of how extensive they may be. Because radiation effects are cumulative, a weekly permissible limit of radiation has been established, and in extreme cases maximum permissible exposure may occur within only a few minutes. Thus, on occasion in extreme cases, replacement of a small electric motor may require a steady rotation of craftsmen: one to disconnect a single lead, the second another, and so on until an entire crew may have received their permissible dose.

Maintenance work is further complicated by the protective clothing that is generally required in the radiation zones. Also material removed from the reactor or its auxiliaries poses disposal and decontamination problems. An indication of the magnitude of

the maintenance problem is that the maintenance organization at the Hanford, Washington, plant contains approximately 35 per cent of the operating personnel and is responsible for the expenditure of about 20 per cent of the total operating budget of the reactor field organization.

T. G. LeClair of the Commonwealth Edison Co., in a paper entitled "Present Feasibility of a Nuclear Power Plant," stated that his organization favors, as an initial development, the use of a simple form of reactor with a solid metal as a fuel and employing heavy or light water as the coolant. The reason for favoring this design is that it appears possible to go ahead with the design of an electric plant promptly without waiting for the solution of some of the more difficult problems of handling molten metals and radioactive materials at elevated temperatures. Noting that this design may be less economical a decade hence than other contemplated designs, Mr. LeClair commented that progress comes from doing rather than theorizing and that operating experience is desirable in order to face some of the problems directly. Also he pointed out that many periods of a decade in boiler design have seen radical efficiency increases, with the result that the older units were retained in service for their physical lives, although relegated to lower load-factor service. By building a full scale reactor of the type proposed, the country can gain experience without waiting to solve all the research problems of a future design.

Construction of a full-scale nuclear power plant now would provide a valuable military asset because it would be in a position to manufacture weapons - grade plutonium continuously if necessary. The plant could be built in such a way that, should the reactor become inoperable for any reason, installation of topping turbines and high-pressure boilers could be made. If plutonium is not necessary during peace time, the plant could operate to produce electric power on a basis of availability for later conversion to plutonium production, providing dispersed production sources for that material. Mr. LeClair concluded by voicing confidence in the advancement of engineering to the point of proceeding with the design and construction of a nuclear power plant. He expressed the hope that the economic, social and financial problems can be solved promptly enough to maintain this country's leading position in the nuclear-power field.

Utility Rate Making

Although the use of electricity has grown many fold in the past 35 years and many theories and practices of rate making have been utilized, the fundamental philosophy of forward-looking utility companies has remained unchanged, according to **L. R. Lefferson** of Ebasco Service, Inc. That philosophy is to encourage the greatest use of the service by the greatest number of customers at the lowest possible cost, consistent with sufficient earnings to provide good service and to maintain financial integrity. In a paper entitled "Fundamentals of Electric Rate Making" Mr. Lefferson pointed out that this philosophy resulted in an uninterrupted stream of rate reductions for twenty-five years prior to 1947 when this trend was halted by inflationary forces. Likewise, it has played an important part in the growth of the country.

European Power Costs

Although the cost of generating electric power probably will increase in the future in Europe, the total relative cost of electric energy will remain stationary or continue the downward trend of the past fifteen years. This statement was made by **P. A. Abetti** of the General Electric Co. in a paper entitled "Economic Aspects of European Electric Power Development." He added that acute power shortages in recent years in Western Europe have stimulated international exchanges, and that plans have been made for the unification of the national systems and the construction of an European super grid which would tie together systems from Scandinavia to Italy and from Spain to Austria. At the same time, decrease of coal imports from countries in the Russian orbit, lack of foreign currency for purchasing coal abroad, and tendencies toward self-sufficiency have greatly stimulated the development of European hydroelectric resources on a national and an international basis.

In analyzing the European power situation, Mr. Abetti paraphrased the agrarian economy theory of the classical English economist, David Ricardo, and held that electricity is as necessary as food to maintain a normal standard of living. He asserted that the European need for integration of power systems will increase with time and that the demand for electric power will increase even faster than the demand for food.

Taking into account current conditions, Mr. Abetti offered the following conclusions:

1. The absolute cost of generating electric power will increase in the future, since the most favorable sources are tapped first. However,

cost of transmitting power will not increase as much as that of generation.

2. Since there are large periodic diversities in hydroelectric generation and the load, there is need for thermoelectric integration in certain zones. Beyond these zones all power must be generated thermally by plants which utilize transported coal or, eventually, atomic fuels. This need for integration will increase with time.

3. Interconnections are very important and have, economically speaking, the same effect as improvement in the quality of generated power. Their prime justification is that they reduce the cost of electric power.

4. Free exchange of electric energy across political frontiers is advantageous and desirable. In Europe this may be accomplished by a very tight interconnection of the various national systems.

Power-Station Efficiency

Electric power-station efficiency is improving rapidly according to **A. E. Knowlton,** associate editor of *Electrical World*, who summarized his publication's Eighth Steam Station Cost Survey. Data were compiled from 43 new plants aggregating a capacity of 6,800,000 kw and a 1952 output of 34,000,000,000 kwhr. The survey showed that generating costs remained stabilized in 1952 and that plant-construction costs are down several per cent from 1950, although still 50 to 60 per cent above prewar levels. It also indicates that kilowatts per plant employee remained unchanged in large plants but increased substantially in medium-sized plants, causing a considerable man-hour saving.

Among the conclusions drawn from the study were the following:

1. Plants for operation in 1952 were built for \$90 to \$165 per kw. Coal-burning plants ranged from \$100 to \$165; oil, from \$145 to \$150; and gas, from \$90 to \$135.

2. Average stations cost \$130 to \$135 against a \$145–\$150 figure in 1950. However, these do not exactly reflect 1953 price levels, as the plants in question were designed and built in the 1948–51 period.

3. Outdoor plants save from \$5 to \$25 in investment per kilowatt.

4. Reheat is the universal choice among new plants operating above 1400 psig. Compared to non-reheat plants, the thermal performance of reheat units is 4 to 24 per cent better. For 2000-psig reheat plants, heat rates are 25 per cent better than 900 psig non-reheat installations.

5. Plant operation factors at 70 per cent were some ten per cent lower in 1952 than in 1950.

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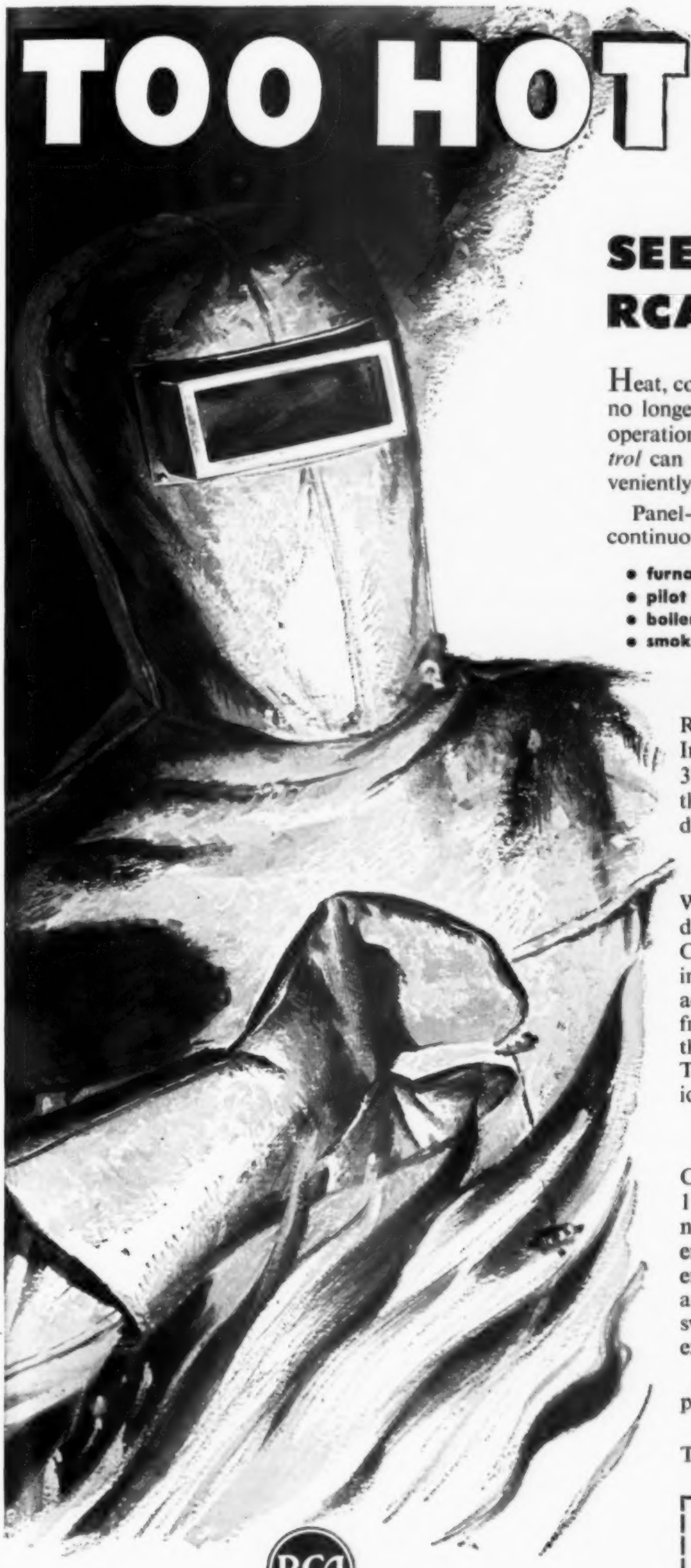

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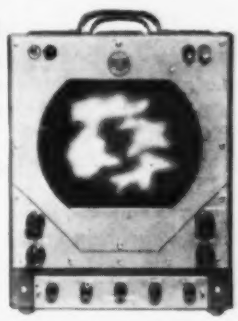

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Controlling SO_3 Content of Flue Gases

Experience in Great Britain in controlling the SO_3 content in flue gases is described in an article entitled "The Influence of Certain Smokes and Dusts on the SO_3 Content of the Flue Gases in Power-Station Boilers" by P. F. Corbett and D. Flint, which appeared in the May 1953 issue of the *Journal of the Institute of Fuel*. Based upon experimental work conducted by the British Coal Utilization Research Association, the article describes the effects upon external fouling and corrosion resulting from the addition of zinc compounds to flue gas. Other tests were carried out to assess the deposition and corrosive effects of auxiliary firing of pulverized coal in stoker-fired boilers.

Five different boilers were used for the experiments, four of which were fired with chain-grate stokers and the fifth with a multiple-retort stoker. Their capacity ranges were from 400,000 to 135,000 lb of steam per hour; pressure, from 2000 to 375 psig; and steam temperature, from 950 to 800 F.

Preliminary tests with zinc oxide confirmed that a sufficiency of fine particulate matter could remove, or inhibit, the formation of SO_3 in the flue gas. On occasions, additions of as little as 0.25 per cent zinc by weight of fuel burned were sufficient to remove a sulfuric acid dewpoint of 310 F.

In discussing the experimental findings, the authors made the following statements:

"Although it is not possible, on account of fuel and operational variables, to draw comparison between all the tests and all the boilers tested, it is nevertheless clear that a *sufficient* addition of reactive smokes or dusts can remove *all* trace of the acid and salt deposits which are believed to be the major cause of air-heater corrosion and bonded deposits."

However, the search for zinc-containing waste materials was discontinued because of difficulties in obtaining even mixing with the fuel and because of the toxic nature of zinc emission from stacks.

The use of auxiliary pulverized-coal firing in conjunction with stokers caused a reduction in the rate of acid deposition which was partially attributed to the fact that much less fuel is burned on the grate at maximum rates of pulverized firing. On the other hand, in other tests manual addition of pulverized fuel dust into the secondary air stream before the forced-draft fan was found to have a beneficial effect. In one instance in which this dust was added at a rate of 20 lb per minute the initial acid dewpoint of 350 F disappeared completely, leaving only a water dewpoint. After the dust addition was stopped, the acid dewpoint immediately reappeared in the flue gas.

Haskell Becomes Vice Chairman of C-E

Announcement has been made by J. V. Santry, chairman of Combustion Engineering, Inc., that **Broderick Haskell,** a member of the Board of Directors and of the Executive Committee of that Company for the past ten years, has been elected vice chairman of the Company. Accordingly, Mr. Haskell has resigned as a vice president of the Guaranty Trust Company of New York.

After graduating from Massachusetts Institute of Technology in 1922, Mr. Haskell devoted a number of years to engineering work in the railway locomotive industry. Later entering the investment banking business, he joined the Guaranty Company in 1930 and subsequently became associated with the Guaranty Trust Company as a vice president.

During World War II he served the Navy as a civilian consultant on financial policy and had an active part in developing methods of financing War Production and related facilities through the banking system.

His long and intimate association with the management of Combustion, as well as his engineering and financial background, particularly qualify him for the position of vice chairman of Combustion Engineering.

Personals

Walter H. Sammis, president of the Ohio Edison Company, was elected president of the Edison Electric Institute at its recent annual meeting in Atlantic City.

Ford Kurtz has been made president of J. G. White Engineering Corp., New York, succeeding the late Gano Dunn. Mr. Kurtz, a Cornell graduate of 1907, had been vice president in charge of engineering for the consultants since 1949.

Gordon B. Carson, formerly a member of the engineering faculty of Case Institute of Technology, has been appointed dean of engineering at Ohio State University, Columbus, Ohio. He succeeds the late Charles E. MacQuigg.

C. H. Fellows, director of research at The Detroit Edison Co. and well known for his work on water treatment and corrosion, has been elected a vice president of the American Society for Testing Materials.

H. H. Gorrie has been named chief engineer of Bailey Meter Co. Joining the Company in 1927, shortly after graduation from Rensselaer Polytechnic Institute, he became assistant chief engineer in 1944.

Dr. Harold Hartley, British engineer widely known in the fields of fuel and power, is the recipient of the Melchett Medal for 1953, which was recently presented to him by The Institute of Fuel.

Eric G. Peterson has lately been appointed executive vice president of Peabody Engineering Corp., New York. He has been associated with that organization for the last twenty-five years.

F. L. Whitney, formerly eastern district chief engineer for the H. K. Ferguson Co., has been appointed chief engineer of Walter Kidde Constructors, Inc.

Harry Knecht, assistant mechanical plant engineer of the Consolidated Edison Co. of New York, Inc., has been elected chairman of the Executive Committee of the Metropolitan Section of the American Society of Mechanical Engineers.

Obituaries

Albert W. Raymond, European manager of Combustion Engineering, Inc., died at Roosevelt Hospital, New York, on June 18. Born and raised in Evanston, Illinois, he attended Columbia University and latter joined Raymond Bros. Impact Pulverizer Company of Chicago—a firm founded by his father and uncle in 1887. After serving with the U. S. Forces in World War I, he was made manager of that company's French affiliate—Raymond Fréres of Paris, renamed Société Anonyme des Foyers Automatiques of France after Raymond

Bros. had become a part of Combustion Engineering.

During World War II, Mr. Raymond served with the Ambulance Service abroad and was taken prisoner by the German Army. He was later decorated by the French Government. Following the war he rejoined Combustion Engineering, and for the past several years has been its European Manager with headquarters in Paris.

Mr. Raymond is survived by his wife, two daughters, a son, a brother, three sisters and eight grandchildren.

Edwin Jowett, retired vice president in charge of plants and production of the Kansas City Power & Light Co., died on June 9. Born in England and the son of a well-known British engineer, Mr. Jowett devoted some fifty years to the practice of engineering before his retirement in 1934. Prior to joining the Kansas City company in 1917, he had been associated with utilities in Texas and Illinois and with several consulting engineering firms. Among his major accomplishments were the design and construction of the Northeast and the Grand Avenue Power Stations in Kansas City.

Walter S. Finlay, Jr., executive vice president of J. G. White Engineering Corp., New York, died on June 17 following a long illness. Born in Hoboken, New Jersey, 70 years ago, Mr. Finlay graduated from Cornell University in 1904 with the degree of mechanical engineer, and after a few years in construction work took a position with the Interborough Rapid Transit Co. in New York City, subsequently becoming superintendent of power. In 1920 he joined the American Water Works & Electric Co., a holding company, as vice president, and seven years later became president of the West Penn Electric Co. In 1939 he joined J. G. White as vice president, becoming executive vice president in 1940.

Highlights of Annual Engineering Education Meeting

MORE than 2000 teachers of engineering and industrialists interested in engineering education took part in the 61st Annual Meeting of the American Society for Engineering Education at the University of Florida, Gainesville, June 22–26. A five-fold theme was reiterated in many ways by the more than 200 persons who presented papers and engaged in panel discussions:

1. Making better use of engineering manpower.
2. Seeking to remedy teaching shortages at the college level and among high-school teachers of mathematics and physical science.
3. Closer cooperation between engineering education and industry.
4. Raising professional standards through emphasis upon ethical creeds.
5. Sharing American scientific knowledge with other countries of the free world.

In his presidential address before the Society, Dean W. R. Woolrich of the University of Texas cautioned that there are some forces influencing the engineering profession which need careful watching. One of these is the attempt of certain unions to place the average engineer in a class with tradesmen, particularly with respect to collective bargaining. On the other hand, some areas of industry have been unrealistic in adjustment of salaries, with the result that those for beginning engineers have risen at a much faster ratio than have the increments for qualified engineers of five, ten and twenty years of service. The Dean emphasized that it is essential for the salaries of accomplished and experienced engineers to serve as an incentive for men entering the profession.

At the annual banquet Dr. Harry S. Rogers, president of Brooklyn Polytechnic Institute, was awarded the Lamme Award as the year's distinguished engineering educator and contributor to engineering research. Prof. Edward F. Obert of Northwestern University, widely known in the heat-power field for his thermodynamics texts, received the George Westinghouse Award in recognition of his outstanding ability as a young engineering teacher. The first two honorary memberships ever conferred by the Society were bestowed upon Dean A. A. Potter of Purdue University and Dean Emeritus Henry P. Hammond of Pennsylvania State College.

Engineering Leadership

In an address entitled "Dependence of Engineering Leadership on Mechanics and Physics," Dean L. E. Grinter of the University of Florida, incoming president of the Society, asserted that much specialization in the undergraduate curriculum now exists in order to justify the use of the professional engineering designations of civil, mechanical and electrical engineer. He contended that these specializations have less significance today than a generation ago and that emphasis should be upon education in the field of engineering science, including increased stress upon the study of mathematics, physics and chemistry.

Dean C. J. Freund of the University of Detroit gave a preliminary report of the committee on ethics. A survey conducted by that group showed that ethical and moral standards remain high among engineers, but that colleges should develop a more positive program for teaching students in terms of ethics. The important matter is that faculties take this responsibility seriously and, working toward it, institute reliable checks to make certain that the responsibility is fully executed.

Research Activity

In a panel discussion on the encouragement of fundamental research, Dr. Joseph W. Barker of the Research Corporation found a danger in too much dependence on the part of engineering schools upon federal support. He expressed the belief that acceptance of classified government research beyond "public service in emergency conditions" as a means of carrying institutional overhead is in the same category as acceptance of direct government educational subsidy. He added that institutions should be prepared to accept or refuse contract research, except in time of emergency, as best serves long run educational interests.

Dean Harold Hazen of the Massachusetts Institute of Technology stated that research by faculty members makes them actual participants in the engineering world, catalyzes their associations with others in the profession, and breaks through ivory-tower isolation. Faculty research aids closer relations with industry and has contributed to the increase of areas of common interest.

Education for Nuclear Engineering

In discussing education for participants in an expanding nuclear industry, James W. Parker of the Detroit Edison Co. expressed the belief that the engineer making contributions in this field will employ the same underlying principles upon which engineering practice has depended in the past. His undergraduate training should be the same as for other fields, except that there should be more advanced work in mathematics. Mr. Parker added that the solid core of undergraduate studies should continue to be courses in engineering mechanics, thermodynamics, heat transfer, materials of engineering and the design of structures and machines. Some place should be made for introductory courses in the application of theoretical physics in the production of nuclear energy and dealing also with nuclear-engineering measurement and instrumentation. Extensive training in nuclear theory should be postponed to graduate study following some experience in engineering practice.

A. J. Gracia of the Goodyear Rubber Company made a plea for engineering "generalists" as well as specialists to enter the nuclear energy field. He added that there is a need for a creative, constructive, synthetic approach to nuclear problems rather than a narrow, analytical approach. The student must have the capacity to deal with the new and unfamiliar with confidence. The growing nuclear industry needs engineers who are (1) educated as whole men and (2) well grounded in fundamentals.

Research in Heat Power

According to Prof. R. G. Folsom of the University of California, the overall objective of research in the university is for the education of staff and students as well as to contribute to the sum total of knowledge. Applied research and development in heat engines is devoted to basic operations, combined operations and performance of machines and plants. Basic operations in combustion may be considered as fluid flow, heat transfer and reaction kinetics. On the other hand, combustion may be considered as a basic operation to steam production which is a combined operation. Prof. Folsom stated that it is necessary to give more consideration to statistical planning in experimental work in order to avoid spending excessive sums of tests involving unrelated variables. Typical mechanical engineering theses at the University of California include studies of turbulence in liquid pipe flow, local boiling in vertical tubes, a water-channel analogy to a problem in gaseous combustion, mass transfer in a rising bubble, and effect of packing density in a cooling tower.

New Catalogs and Bulletins

Any of these may be secured by writing Combustion Publishing Company, 200 Madison Avenue, New York 16, N. Y.

Pipe Hangers

A 12-page bulletin describing the Counterpoise pipe hanger for high-temperature piping systems in steam generating stations, refineries and chemical plants has been released by the National Valve & Manufacturing Co. Graphs for aid in selecting proper hangers, tables of dimensions, plus erection and field-adjustment instructions are given in Bulletin 153.

Screw Pumps

Warren Steam Pump Co., Inc., has made available a twelve-page, two-color bulletin, No. S-205, which is concerned with Warren-Quimby screw pumps. Basic construction and design are discussed in detail, and there are sectional views with indicated features; also external and installation illustrations, dimensions and specifications.

Gas Analysis Equipment

Information about electronic Speedomax Recorders and Controllers is now available in an eight-page folder, No. ND46-91(2), "Speedomax Gas Analysis Equipment for Thermal Conductivity Measurements," published by Leeds & Northrup Co. The bulletin lists performance characteristics and shows how the equipment incorporates the thermal conductivity method for accurate measurements.

Film-Type Amine

The Hagan Corp. has made available a bulletin describing the advantages of a new film-formine amine designated as Hagafilm. The material, which is available in solid and liquid forms, is fed to the boiler, vaporizes with the steam, and deposits a thin, nonwettable protective film on metal surfaces wherever condensation occurs and throughout the return system.

Power Packs

An eight-page illustrated bulletin on Inductrol Power Packs for a-c lighting and power service up to 112.5 kva, 600 volts and below has been announced as available by the General Electric Co. The bulletin (GEA-5928) explains reasons for voltage regulations and outlines advantages of using packaged equipment to provide such regulation.